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Improvements introduced by the Italian State Railways,

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Figs. 1 to 14, pp. 810 to 828.

Lines and equipment.

The system operated by the Italian State Railway Administration extends to-day to a total of 16 600 km. (10 314 miles), of which 730 km. (454 miles) is narrow gauge.

The construction of the system involved considerable technical difficulties owing to the geographic and geological conformation of the country. The great differences of level increased the cost of construction, as it involved increases in length, the building of bridges, tunnels, viaducts, and works of protection.

To give some idea of the difficulties of operating the Italian system, it may be pointed out that the ratio between the actual work required to haul the trains and that which would be enough to operate the same traffic on level lines is as 130 to 100.

In addition, the total length of line in tunnel is about 850 km. (528 miles) [on the Spezia-Genoa line, 88 km. (55 miles) long, 47 km. (29 miles) are in tunnel].

The total number of bridges exceeds 10 000, of which 4 600 are metal, and the others masonry or ferro-concrete.

The present system, which is reasonably uniformly distributed throughout the different parts of Italy, in relation to the population [per 10 000 inhabitants, there is 4.9 km. (3 miles) of lines in the North, 5.5 km. (3.4 miles) in the centre, 5 km. (3.1 miles) in the south, and 5.9 km. (3.7 miles) in the islands] has up to the present met the traffic requirements. It has, however, been recognised that a number of improvements was required to better meet the goods and passenger traffic requirements, and also to assist in competing with other more modern forms of transport.

We will give here a review of the different measures that for some time have been the object of careful investigation, and which to-day are being put into oper-

Fig. 1. — The Italian State Railway system showing the lines actually laid with heavy rails (92.73 to 100.80 lb. per yard).

ation as a result of the vigorous impulse the Fascist Government has given to the whole life of the nation.

We have provided, and continue to provide, for the construction of new lines which should, in particular, favour the longitudinal traffic, the most important on our system owing to the long narrow formation of the Italian peninsula.

During the year 1924, the Bologna-Verona line was completed, whereby new and quicker communication between the centre of Italy and the south on one side, and with the Brenner and Southern Germany on the other, was given.

In October 1927, the direct Rome-Naples line (215 km. = 133.6 miles) was opened to working, which although the actual distance between the two cities was only reduced by 33 km. (20.5 miles) as regards the old line through Cassino, has given great advantages as a main line for heavy traffic. It has been built without level crossings, has no gradients exceeding 1 %, nor curves of less than 800 m. (40 chains) radius (the line through Cassino has gradients of up to 1.7 % and curves of 500 m. [25 chains] radius).

It has been possible to run very fast trains over this section taking two hours and 50 minutes, whereas over the old line the express trains took four hours and 15 minutes.

The new line which at present terminates at Naples-Mergellina, in the centre of Naples, is principally used for passenger traffic. There is, however, under construction a branch between Villa Literno and Aversa station on the Naples-Foggia line, which will enable *passenger and goods traffic* to get into the Naples central station also by the direct line and then to go forwards directly towards Southern Italy.

Other new lines of a length of 550 km. (342 miles) including 100 km. (62 miles) narrow gauge are in construction.

Among the standard gauge lines, particular mention should be made of the international Cuneo-Vintimille line which runs partly through French territory. Two sections are in use — the first and the last — from Cuneo to S. Dalmazzo di Tenda (60 km. = 37.3 miles) and from Vintimille to Airole (12 km. = 7.5 miles). During the current year the central section will be opened (25 km. = 15.5 miles) between Airole and S. Dalmazzo, (20 km. = 12.4 miles), being in French territory.

On the French section the international station of Breil has been built and from it the new branch between Cuneo and Nice (60 km. = 37.3 miles) is being built. The branch for a short distance (entirely under tunnel) passes through Italian territory, and the remainder runs over French territory. The whole of the Cuneo-Vintimille line will be operated by the Italian State Railways and will be electrified with low tension three-phase current.

The Breil-Nice section will be operated by the French Paris, Lyons, and Mediterranean Railway, and will also be electrified.

Another very important line under construction is the through Bologna-Florence railway which has been re-aligned between Bologna and Prato, whilst using between Prato and Florence the section — double track — of the present Bologna-Poretta-Florence line.

The new line will very greatly relieve the present Porrettana line which was built 64 years ago in accordance with the practice of that time, and could no longer meet the present traffic requirements, although its capacity had been increased by its recent electrification.

The said direct line, which will have

the physical characteristics of the main lines, has also great technical interest on account of the long tunnel through the Apennines.

This tunnel will be one of the greatest works on any railway in the world, both for the length (18.5 km. = 11.5 miles) and for the difficulties its construction involved as it had to be drilled through soft rock which involved linings and protection works of considerable thickness. The tunnel was started both at the two ends and at intermediate points by means of inclined shafts. The width of the tunnel is (for a double track line) 8.57 m. (28 ft. 1 1/2 in.), but the centre section is enlarged to 15 m. (49 ft. 2 1/2 in.) to provide for an intermediate station with two passing lines.

The other standard gauge lines in construction are : Fossano - Mondovi - Ceva (37 km. = 23 miles); Ostiglia-Treviso (117 km. = 72.7 miles); Sacile-Pinzano (67 km. = 41.6 miles); Vittorio Veneto-Ponte nelle Alpi (26 km. = 16.2 miles); the centre section of the Aulla-Lucca line, *i. e.*, the section from Monzone to Castelnuovo di Garfagnana (27 km. = 16.8 miles); and others less important.

All the narrow gauge lines in construction form part of the secondary system of Sicily.

On the lines in operation, the Administration of the State Railways is pressing forward the works necessary to complete double tracking the principal arteries. During these last years important sections have been completed.

In particular we may note : the last section between Giuncarico - Montepescali (which was wanted to give double track the whole length of the important line of the Maremma between Leghorn and Rome) and the section Zoagli-Camogli (wanted to give a double track line between Genoa-Sestri Levante). To complete the double track on the whole of the trunk line between Rome and Genoa, there is still about 40 km. (25 miles) to be done between Spezia and Riva Trigosco, which is actively in hand in spite of serious difficulties owing to the large number of tunnels and viaducts.

On the dorsal line, Rome-Florence also, work is in hand on double tracking a section of 50 km. (31 miles) where single track still exists, and which has special difficulties.

When the laying of these double lines is completed, and the direct Bologna-Florence line is opened to traffic, we shall have an uninterrupted line from Naples to Milan capable of dealing with heavy traffic, and which will enormously assist the development of traffic between the north and south of Italy.

The express trains will then be able to cover the 850 km. (528 miles) between Milan and Naples in 11 hours.

Quite recently double track has been laid between Aversa-Casoria-Naples which will form part of the avoiding line Villa Literno-Naples of the new Rome-Naples line.

On the Adriatic coast line, there is now double track between Bologna and Ancona, and on the short sections which are quite close to the most important centres of Foggia and Bari. Work is now in hand on the following sections : Ancono-S. Benedetto del Tronto (83 km. = 51.6 miles), Foggia-S. Severo (28 km. = 17.4 miles, and Barletta-S. Spirito-Bitonto (45 km. = 28 miles), as well as on other sections of less importance, amounting in all to 200 km. (124 miles).

When these works have been completed, the double track lines of the State system will have a total development of about

4 000 km. (2 485 miles), that is to say, 25 % of the whole system.

Another important problem in course of solution in order to modernise the Italian lines is the strengthening of the permanent way and of the metal bridges.

As regards the permanent way, the lines of the Italian State system may be taken as having, as a general rule, rails weighing 36 kgr. per metre (72.57 lb. per yard) with 14 sleepers per each 12 m. (39 ft. 4 1/2 in.) rail. In this way they can carry a maximum weight of 15 metric tons (14.76 English tons) per axle.

In order, however, to meet the latest requirements of the traffic department, more powerful and faster locomotives, with weights exceeding 15 metric tons per axle, have to be used. It has been necessary to make provision for strengthening the track on some sections by increasing the number of sleepers (16 or 17 per rail), and on others by using another and heavier pattern rail [of 46 kgr. (92.73 lb. per yard) on level sections, and 50 kgr. (100.80 lb. per yard) on gradients and in tunnels]. The works programme to be completed as quickly as possible includes the strengthening of the permanent way on 10 000 km. (6 214 miles) of single track, and the renewal of the rails on a further 10 000 km. (6 214 miles) of track.

On the strengthened lines, which at present amount to 6 000 km. (3 728 miles) the maximum axle weight can be 16.5 metric tons (16.25 English tons). On track with heavy rails 20 or 21 metric tons (19.68 or 20.67 English tons) can be allowed. These rails to date have been laid on the Milan-Venice, Milan-Bologna-Pistoia, Milan-Genoa, Genoa-Leghorn, Chiusi-Rome-Naples lines, as well as on other sections having a total length of about 5 000 km. (3 107 miles) of single line.

In order to allow modern locomotives of heavy weight and high speed to be used on the most important lines of the System, the renewal of metal bridges (which number about 4 600) has been energetically taken in hand.

The bridges which have been, or which will shortly be, systematically strengthened by replacing the old structures by new bridges of steel, reinforced concrete, or masonry, number about 400 with a total length of nearly 10 000 m. (32 800 feet).

On the Battipaglia-Reggio Calabria line alone, 26 large bridges have been renewed as well as many other smaller ones.

Very important works have also been carried out in extending passenger and goods stations at the principal centres. Only the most important need be recalled here : the new station at Milan, of which the approach lines are completed, and the work on the monumental passenger station and the other large buildings, all metal, over the platforms, having an area of 66 500 m² (715 800 square feet) : the largest railway platforms in Europe, is being pushed forward.

The improvements at Turin include the lowering of the level of the rails (to facilitate traffic in the city) and the new goods station at Vanchiglia.

At Florence, after improving the line towards Leghorn and the branch between Rifredi and Le Cascine, and having enlarged these two stations, the locomotive shed which was near the Santa Maria Nuova station has been removed to Il Romito. The said station will be altered so as to better meet traffic requirements and to bring the buildings into line with the artistic requirements of the city.

As has been done at Florence, in other important centres (Bologna, Leghorn, Foggia, Bari, Benevento) the locomotive shed has been, or will be, removed. In this way the land required for extending

Fig. 2. — Naples-Mergellina station (Rome-Naples direct line).

Fig. 3. — Naples-Mergellina station (Rome-Naples direct line).

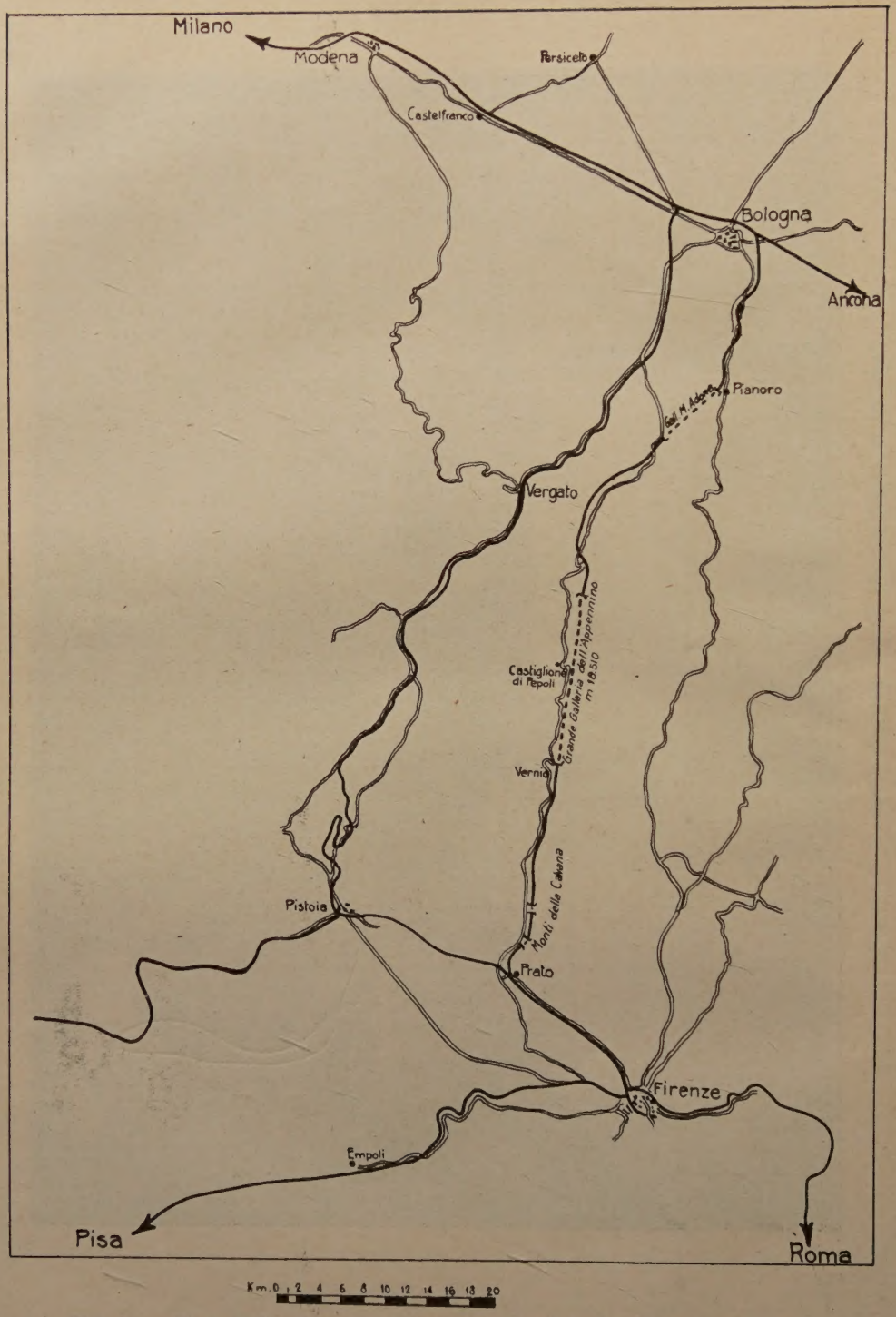

Fig. 4. — Plan of the Porrettana line and of the Bologna-Prato direct line

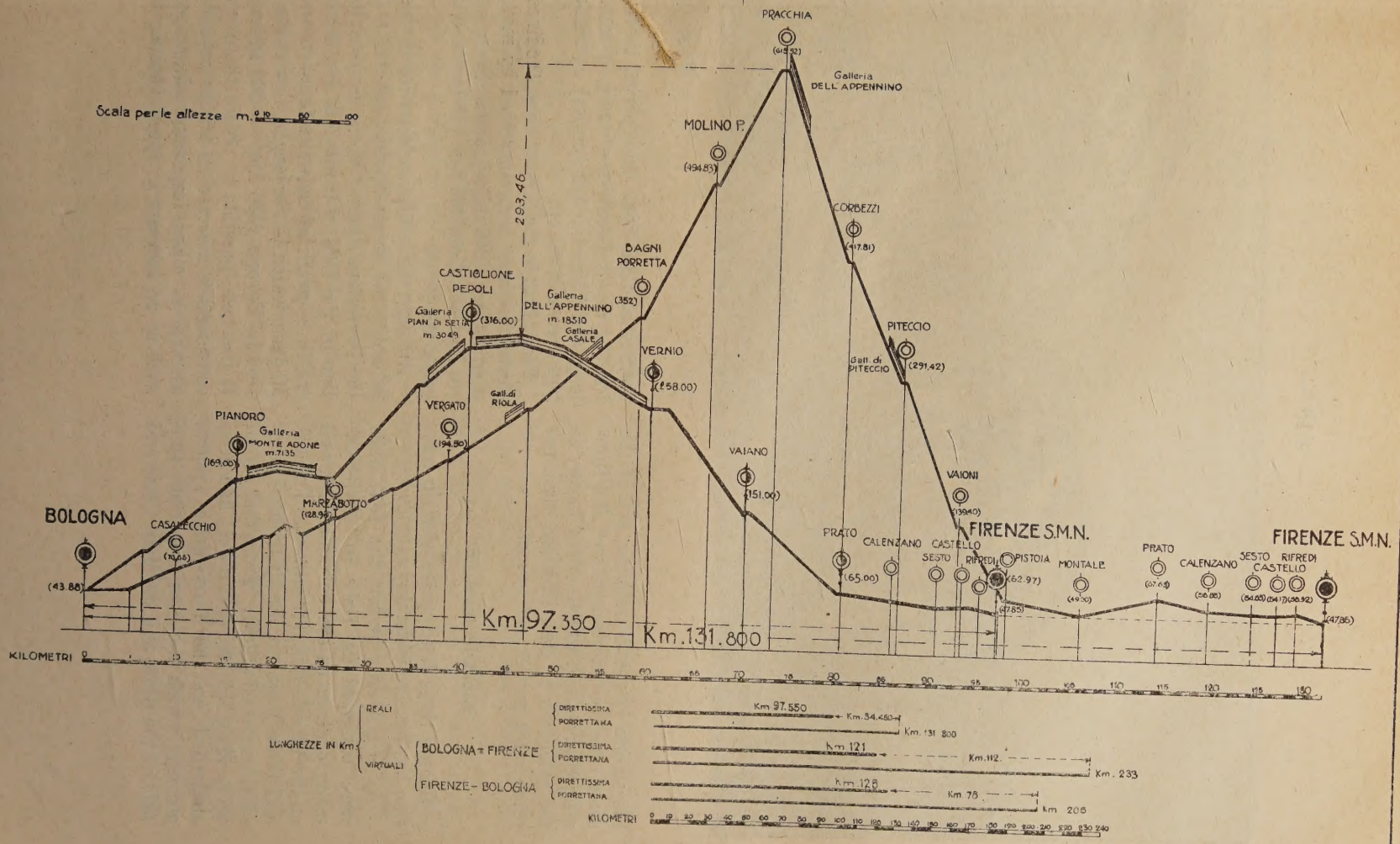

Fig. 5. — Profile of the Bologna-Florence direct line and of the Porrettana line.

Explanation of Italian terms: Direttissima = Direct. — Galleria = Tunnel. — Lunghezze = Lengths. — Reali = Actual. — Scala per le altezza = Scale of heights. — Virtuali = Virtual.

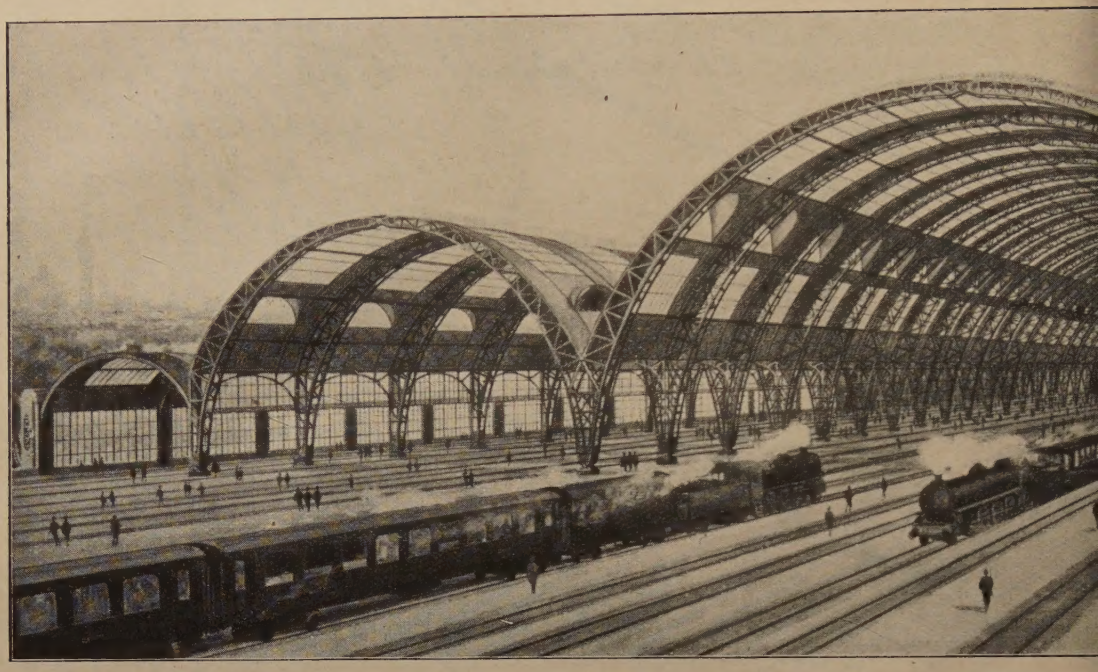

Fig. 6. — Station buildi

the station is made available, and at the same time the requirements of the Running Department, which, owing mostly to the extension of electrification, have become much greater, can be met.

Electric traction.

During these latter years electric traction has been considerably extended.

As is generally known, the first lines were equipped in Italy in 1901-1902, using continuous current and third rail on the Varesine line (73 km. = 45.4 miles) and three-phase on the Valtellinesi lines (106 km. = 66 miles). From that period up to 1923, 550 km. (342 miles) had been electrified on the three-phase system, amongst which the very important tunnels of the Giovi and the Mont Cenis and the Savona-Ceva line. In a period therefore of about twenty-two years, a total length of 730 km. (453.5 miles) of track had been electrified.

From 1923 to the present time, the lines electrified have been increased by more than 450 km. (280 miles), and at the present moment about 450 km. (280 miles are being converted.

Amongst the last lines electrified should be noted the Genoa-Spezia-Leghorn, and the Porrettana lines. With the completion of the first, a trunk line for heavy traffic is available between Leghorn and Modane, which is the longest line electrified in Europe (450 km. = 280 miles). It has been possible to obtain thereby a considerable increase in traffic capacity as well as other important advantages, such as an increase in speed, absence of

y station at Milan.

smoke, much appreciated by passengers over this line on which there are many tunnels. Anyone who had gone over the Genoa-Spezia line several years ago would now find the journey, then very trying — especially in summer — had become a real pleasure as the splendid scenery of this section can now be freely admired.

The electrification of the Porrettana line (Florence-Bagni della Porretta-Bologna) 132 km. (82 miles) of single track with very severe gradients has enabled the working of the line to be greatly improved, and its capacity increased whilst waiting for the opening of the new Bologna-Florence line, which will also be electrified.

Electric traction with continuous current and third rail, as used on the Varesine lines has also been applied to the last section of the direct Rome-Naples lines, that is to say, from Naples to Villa Literno, where an intensive service of trains, metropolitan type, has been organised.

On the whole of the Rome-Naples direct line, continuous current traction at 3 000 volts and overhead line now being tested on the Benevento-Foggia line, will be used.

The three-phase system, which has met, and still meets, very well the traffic requirements on lines with very heavy gradients, is at present used on the Sampierdarena-Ovada-Alexandria (75 km. = 46.6 miles), Bolzano-Brenner (90 km. = 56 miles), and later on will be used on the Savona-Vintimille, Cuneo-Vintimille, Voghera-Milan, Parma-Spezia and Pisa-Pistoia lines. In this way there will be a

Fig 7. — Bridge over the Sele river : three independent spans each of 50 m. (164 feet).
(Battiglia-Reggio-Calabria line.)
The type of span most commonly used at the present time on the Italian State Railways.

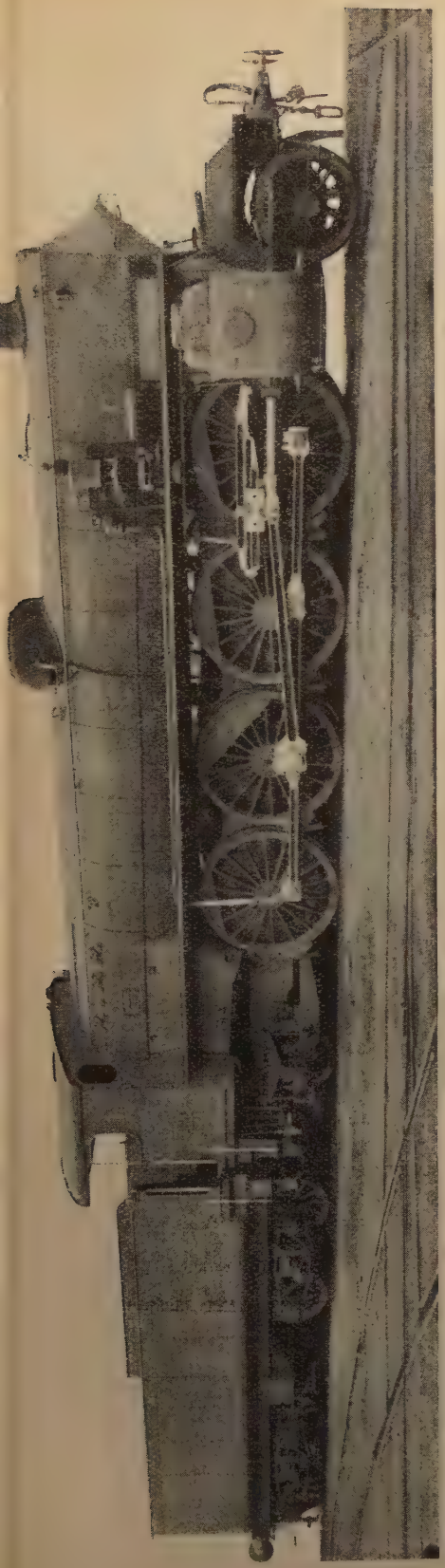

Fig. 8. — 747 type locomotive of the Italian State Railways (1926). — Four cylinder superheated compound with Caprotti valve gear. Weight in working order including tender 144 tons (141.7 English tons).

homogeneous system of about 1 500 km. (932 miles) in Piedmont, Liguria and Tuscany.

It is interesting to note the other system being tried on the Rome-Avezzano-Sulmona line, namely, the three-phase at industrial frequency (45 periods), the object of which is to see if there is any advantage to be gained by including the distribution of energy for traction purposes in the distribution of energy to industrial undertakings.

Including the lines under conversion and those which will be electrified, according to the programme, the total length of lines worked by electric traction on the State system will soon be 2 000 km. (1 243 miles), whilst on the railways operated by private companies, there are another 1 000 km. (621.5 miles) electrified.

In view of the great development of the electrification of its lines, the Administration of the Italian State Railways, although it obtains large supplies of current from private companies, has considered it advisable to build in addition some large hydro-electric plants.

In the year 1901 the Morbegno Central Plant was built to supply the energy required by the first three-phase line to be built (Lecco-Sondrio-Chiavenna). This station is being improved and its power doubled, when the annual output will reach about 35 million kw.-h. For the electric traction of the Turin-Modane line, the Railway Administration has built the Bardonnechia station, using the water from the Melezet and Rochemolles torrents. At the present time this plant is being enlarged to enable it to supply about 50 million kw.-h. per annum.

In the water sheds of the Reno and Limentre rivers in the Etruscan Apennines, the Pavana station is now in

operation and gives 12 million kw.-h. a year for the Porrettana line. The power stations at Suviana and Castrola are in construction with reservoirs of 40 and 30 millions of cubic meters (8 800 and 6 600 million gallons) and dams up to 90 m. (295 feet) high and will give 85 millions of kw.-h. per annum.

Another large hydro-electric station built by the railways is that of the Sagittario close to Anversa-Scanno. It produces about 60 millions of kw.-h. a year for operating the electrified Rome-Sulmona and Benevento-Foggia lines.

Rolling stock.

In addition to the betterment carried out on the lines and the stations the State Railways have also given attention to the improvement of their rolling stock. The existing stock which still suffered from the damage caused during the war has been repaired on a large scale. The stock has been increased by building new vehicles of modern design.

Since 1923 to date, 650 new locomotives and over 20 000 vehicles have been handed over to the operating services.

At the present time 350 locomotives and 10 000 vehicles are under construction.

At the beginning of the war, the Italian State Railways had in service 5 150 steam locomotives of a total horse power of about 3 millions, or an average power of 610 per locomotive.

New locomotives designed by the Italian State Railways, of 1 000 to 1 200 horse power were already in use, and the types 680 and 685 (2-6-2), 690 (4-6-2) for main line passenger trains, 740 and 745 (2-8-0) for the goods trains on lines with moderate gradients, and the 470 type (0-10-0) for heavy trains on mountainous sections should be recalled to mind.

These locomotives, though very powerful, have a weight which does not exceed 15 metric tons (14.76 English tons) per axle so as to be able to run over most of the Italian lines. The locomotives of type 690 alone have a maximum axle weight of 17 metric tons (16.73 English tons), and for that reason can run up to 130 km. (81 miles) an hour only on certain lines having heavy traffic already laid with heavy pattern rails.

The 680 and 470 type locomotives are saturated steam compound four-cylinder engines.

The other engines mentioned are simple expansion superheated engines.

Since the War, the State Railways have given preference to the 685, 740 and 745 types.

The Italian Railways (like nearly all foreign systems) found the superheated simple expansion locomotive gave better results than the compound.

Tests have also been made with satisfactory results on the simultaneous use of compounding and superheating.

The State Railways, after the War, designed further new types of locomotives. It has been found that the 685 type engine, although good in itself, was not powerful enough to avoid double heading, especially on lines with gradients, for the passenger trains which to-day must have more coaches and run at higher speeds.

The locomotive of the 690 type was better for such work, but as we have seen, it could only be used on a limited number of lines. The new 746 type locomotive (2-8-2) was therefore designed, which compared with those of the 690 type, has a lower coupled axle weight [16.2 instead of 17 metric tons (15.94 instead of 16.73 English tons)], has four cylinders, is superheated and is compounded. It has a total weight of 94 metric tons (92.51 Eng-

lish tons) and can develop up to 1 600 H. P. instead of the 1 400 H. P. of the 690 type.

The 746 type locomotive is therefore the most powerful locomotive in the State Railways' possession.

In the same way, in the case of goods trains worked over heavily graded lines, it has been found necessary to have more powerful locomotives than those of the 470 type, and in 1922 the new 480 type was designed and built. The engine also has ten coupled wheels like the 470 type, but has in addition a leading axle forming bogie with the leading coupled axle (type 2-10-0).

Locomotives of this type are simple expansion, superheated engines, and have an axle weight not exceeding 15 metric tons (14.76 English tons), and can develop 1 500 H. P., whereas those of the 470 type can only develop 1 000 to 1 200.

For mountain lines with moderate traffic, six-coupled tank engines were used until 1922. After the war they were unable to haul, unless double headed, the heavier trains that had to be worked over these lines. Locomotives of this type, the 940 type (2-8-2) are superheated compounds and can develop about 1 000 H. P.

Nearly all the new engines of the Italian State Railways have Walschaerts valve gear, but in 1924 it was thought advisable to test the new Italian type of poppet valve gear, the *Caprotti*.

This system has been fitted with satisfactory results to nearly 100 locomotives of the 685, 740, 746 types, which have been given the following new type numbers 686, 741, 747 respectively.

As regards electric traction, at the beginning of the war, 100 locomotives were in use working on low frequency (16.7 periods) three-phase current and 50 motor coaches on continuous current third rail.

There are still 50 motor coaches. The number of locomotives has grown to 530; they are nearly all three-phase, such as the E. 550 type — for heavy trains — ten wheels coupled type (0-10-0) developing 2 000 to 2 700 H. P. at 50 km. (31 miles) an hour. Other locomotives, for fast trains, belong to the E. 330-431 types with six or eight wheels coupled (type 2-6-2, 4-6-4 or 2-8-2) — and can develop 1 500 to 2 700 H. P. at the speed of 75 to 100 km. (46 1/2 to 62 miles) an hour.

The most recent types of electric locomotives now under test are those using three-phase current at industrial frequency (type 470, 472, 570) for the Rome-Sulmona line, and those for overhead continuous current (type 625) for the Foggia-Benevento line.

The locomotives at industrial frequency of the 470 and 472 types (2-8-2) can develop about 1 300 H. P. at 75 to 100 km. (46 1/2 to 62 miles) an hour.

The locomotives of the 570 type are much like the 550 type (0-10-0) and develop about 2 700 H. P. at 50 km. (31 miles) an hour.

These locomotives will be supplied with three-phase current at 45 periods at 10 000 volts at the trolley.

The continuous current over head line locomotives at 3 000 volts of the 625 and 626 types have six axles and six motors. The motors can be coupled in series or parallel to give 9 running speeds. These locomotives develop about 2 000 H. P. at 45 km. (28 miles) (625 type), and 75 km. (46 1/2 miles) (626 type).

The gross horse power of the steam and electric locomotives of the Italian State Railways is to-day about 6 millions. The average horse power per locomotive is 860.

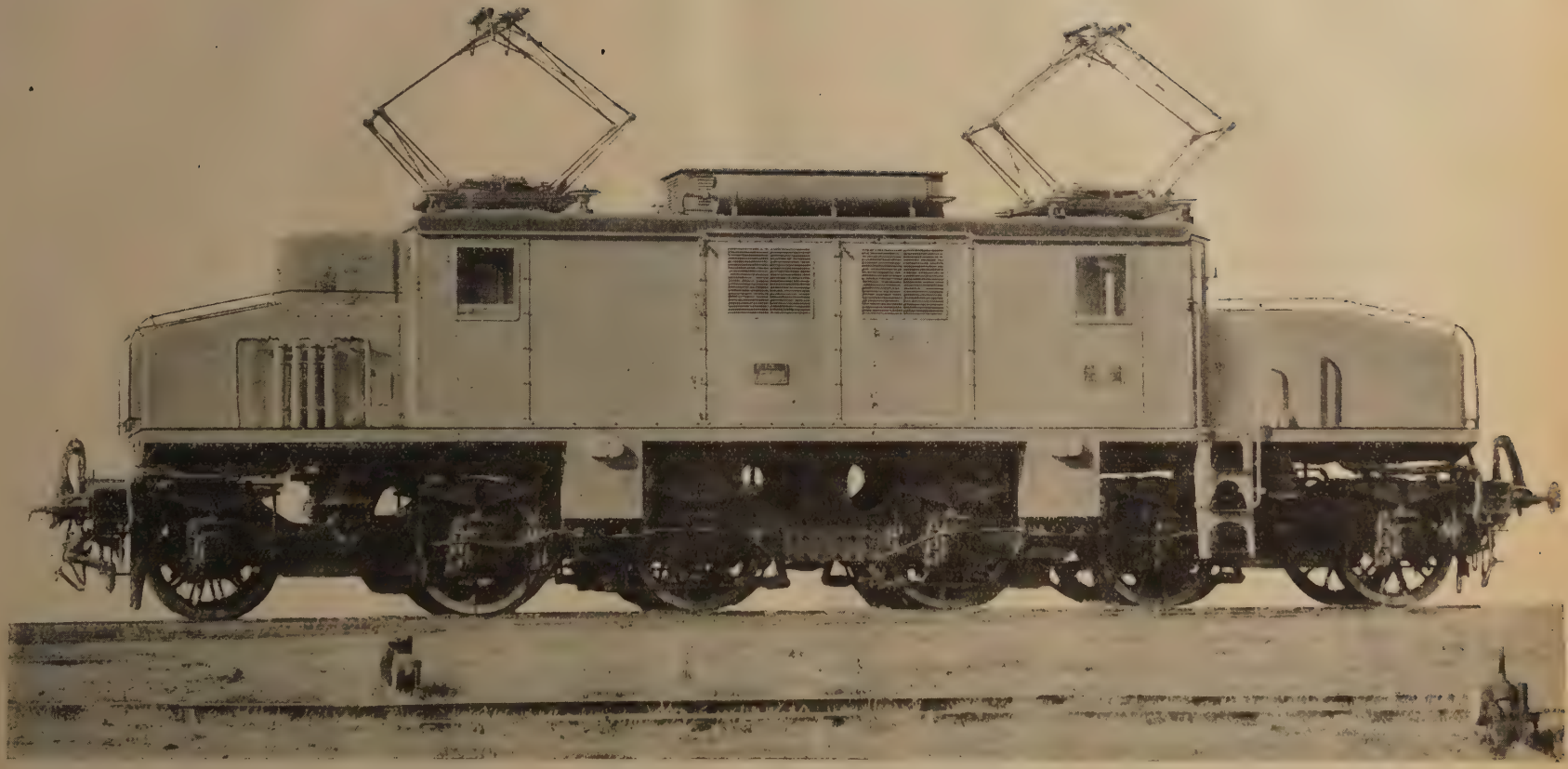

Fig. 9. — Type E 625 continuous current electric locomotive for 3 000 volts.

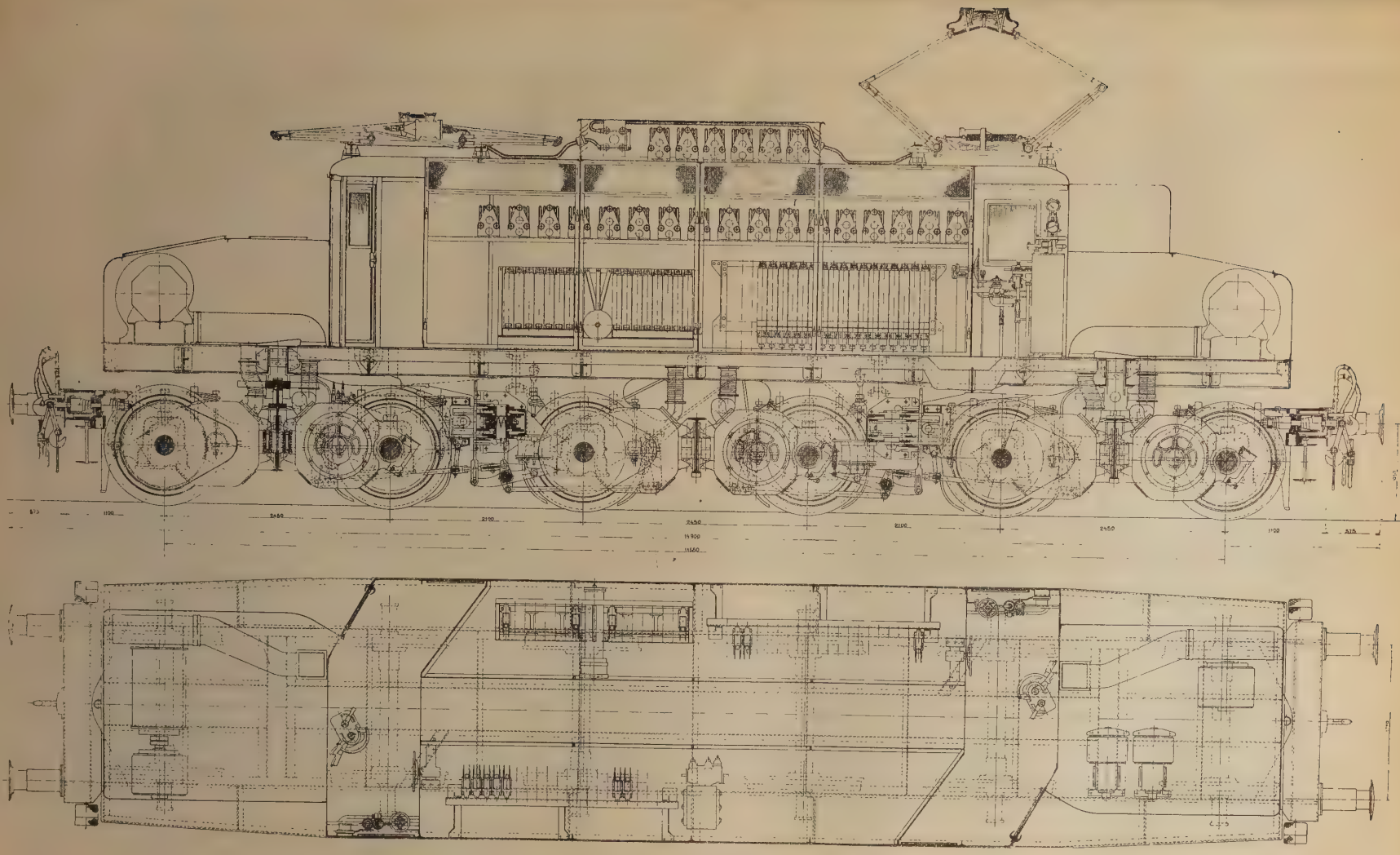

Fig. 10. — Type E 625 continuous current electric locomotive.

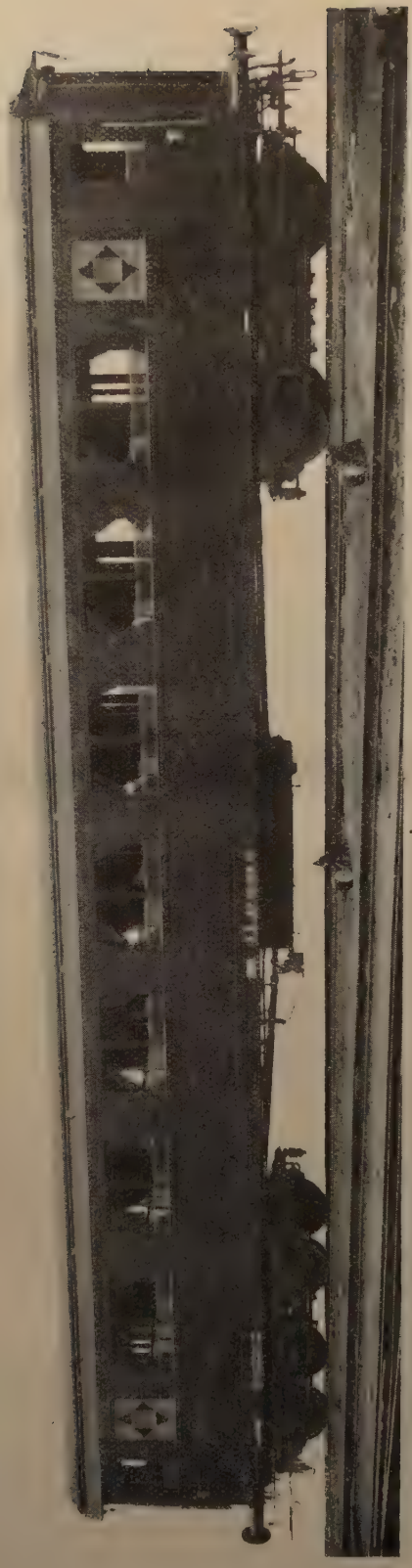

Fig. 11. — New passenger carriage with steel body.

The stock of vehicles is at present composed of :

9 000 carriages giving about half a million seats;

150 000 goods wagons of a capacity of 2 680 000 metric tons (2 638 000 English tons);

4 000 goods brakes.

The carriages are slightly fewer than pre-war, but as a result of the increase in bogie vehicles, there are more seats.

The average capacity of the wagons is 18 metric tons (17.71 English tons), whereas in 1913 it was 15.5 (15.25 English tons).

Amongst the most recent improvements made in the carriages must be noted the construction of steel coaches. Modern trains are heavier and faster. Their acceleration is faster, and braking is greater, and consequently the carriages are subjected to greater stresses than formerly.

As a result, the Italian State Railway designed in 1920 a type of carriage having the body in steel in a single well-built unit able to stand efficiently all stresses and to protect the passengers in case of accident.

The first 150 carriages of this type — composite first and second class — for international service, were put into service in 1923. The practical results were good — passengers considered them comfortable and the Company found their upkeep less costly.

Subsequently 300 more coaches of the three classes were ordered, and are almost all in service, so that the requirements of international traffic are amply covered and modern stock of a single type is available for the most important trains of the system. Five hundred additional carri-

Fig. 12. — New passenger carriage (steel framed body).

Fig. 13. — Third class passenger carriage for international service (steel framed body).

Fig. 14. — New goods wagons for carrying food stuffs.

ages of the same type, first and second class, are now on order.

As regards the wagon stock, important improvements also have been realised. There are at present about 20 000 goods wagons fitted with Westinghouse brakes and 15 000 others piped only. This has made it possible to form such wagons in passenger trains or to run express goods trains.

The Administration of the State Railways has also designed and built wagons for the carriage of different classes of food stuffs, the transport of which is unusually important in Italy.

Since 1924, 15 000 new covered wagons (type F) for the carriage of fruit and vegetables have been put into traffic, these wagons being used for other classes of goods when this particular traffic falls off.

The body of these wagons is entirely in steel. They have double sides with an intermediate space between so that they are well insulated. They have 16 shutters so that they can either be well ventilated or hermetically sealed, according to the class of goods carried.

A special type (type Hg) of these new wagons has been built for the carriage of perishable food stuffs, such as fish, fresh

and chilled meat, milk, etc. The wagons are known as *refrigerators*, but should be considered rather as *insulated*, as the high insulating resistance of the walls and roof (lined with water-proof paper and compressed cork) makes it possible for the goods loaded in them to retain the loading temperature for a long time.

Traffic.

Having considerably improved the rolling stock and reduced the quantity requiring repairs, which was high as a result of war service, the State Railway found it could satisfactorily meet the growing traffic needs.

In the year 1913-1914, when the services were growing with a very satisfactory regularity, the State Railways worked without difficulty :

73 million passenger train-kilometres (45 361 000 passenger train-miles) ;

45 million goods train-kilometres (27 962 000 goods train-miles),

that is to say, an average of :

4 420 passenger train-kilometres per kilometre of track;

2 730 goods train-kilometres per kilometre of track.

The traffic of the said year was about 5 000 million passenger-kilometres (3 110 million passenger miles) and 7 000 million goods ton-kilometres (4 280 million goods English ton-miles). Each passenger train carried an average of *67* passengers, and each goods train *155* metric tons (*152.6* English tons) of goods.

In the very difficult period after the war, the traffic fell off considerably, but consequently — and especially after the National Government had restored order and regular working in this vital public service — passenger and goods traffic returned again to the railways.

The number of passengers increased rapidly from 100 to 118 million, and the weight of goods despatched from 40 to 65 million metric tons.

The passenger traffic in 1926-1927 had reached about 8 300 million passenger-kilometres (5 157 million passenger-miles), and the goods 13 000 million ton-kilometres (7 950 million English ton-miles).

The train kilometrage was 82 millions (50 953 000 train-miles) for passengers and 65 millions (40 390 000 train-miles) for goods, which gave an average of :

5 000 passenger train-kilometres per kilometre of track and 4 000 goods train-kilometres per kilometre of track.

The average load of the trains was 100 passengers in passenger train work and 200 metric tons (196.8 English tons of goods in goods train work.

This definite improvement in the use of the trains is one of the most remarkable features of the present operation methods of the Italian State Railways, and the principal reason will be given below.

First of all, the real improvement in the locomotive stock has made it possible to increase the weight of the trains as compared with pre-war days.

(Average train weight in 1927, 300 metric tons as against 235 [295.2 English tons as against 231.3 English tons] in 1913. Average number of axles in 1927, 24 for passenger trains, 56 for goods, as compared with 20 and 50 in 1913.)

The number of passenger trains has been increased to a greater extent on lines with heavy traffic than on those on which the traffic is small. There are therefore to-day fewer badly loaded trains.

As regards goods trains, the average composition has been increased and there has also been an appreciable increase in the average loading of the wagons.

The average load per axle has been increased from 4.27 to 5.3 metric tons (4.20 to 5.22 English tons) and the load carried per axle, loaded and empty, has increased from 3 to 3.86 tons (2.95 to 3.80 English tons).

The running of the trains is now better, especially on the main lines.

The timing of trains between the most important centres (Turin and Rome, Turin and Milan, Rome, Naples and Reggio-Calabria) is better than in pre-war days, and it must be admitted that formerly the trains ran very late more often than not, whereas passengers now know definitely when they will start and when they will arrive.

The passengers are also aware that they can make use of facilities previously lacking, such as : second class sleepers, night trains exclusively formed of sleeping cars, reservation of seats, etc.

An important novelty much appreciated by the public is the introduction of express trains on the Rome-Naples and Rome-Florence-Milan lines, which do the journey in much less time than formerly (2 h. 50 m. and 10 h. 15 m. respectively). These trains are wholly formed of the very conveniently arranged steel carriages recently put into service.

As regards goods traffic, there has been a real improvement with the introduction of special express goods trains formed of brake-fitted stock.

These trains have made it possible to carry at a high commercial speed, goods (and especially foodstuffs) from the principal centres of production to the centres of consumption as regards the interior, or in transit by land and sea for export, and at the same time to reduce the cost of fuel and staff.

The traffic, which since 1923 has had a rapid and progressive increase, fell off during the year 1926-1927, with even some further reduction during the current year. It was the repercussion of the world economic crisis which similarly affected railway traffic in other countries.

For this reason, the Administration of the State Railways, on the one hand, has given every care to the reduction of the costs of operation, and, on the other, has continued to improve its equipment and stock in order to be ready to meet the traffic requirements when traffic returns, as it undoubtedly will.

Fuel.

Fuel, which plays a very important part in the operation of all railways, is a matter of first importance for the Italian State Railways, both because of the relatively greater consumption due to the many gradients on the system, and because of the higher price the Italian Railways have to pay for foreign coal.

Before the war, the Italian Railways used the best quality Cardiff coal, the consumption being 5.39 to 5.83 kgr. per 100 virtual t.km. (19.43 to 21.02 lb. per 100 virtual ton-miles) of load hauled.

Since 1920, German coal from the Ruhr, which Italy receives on War Reparations account, is almost exclusively used.

With this coal when carefully screened, during the year 1926-1927, the average consumption per 100 virtual ton-kilometres hauled, was 5.67 kgr. (20.44 lb. per 100 virtual ton-miles).

The most important method of obtaining economy in the use of coal is the well known one of interesting the staff in saving coal by instituting coal premiums.

This principle is just and advantageous as regards the enginemen, who are thereby rewarded for their care, but was strongly opposed during the first years

after the war by the Railwayman's Union: after being suppressed for a time, the premiums were re-introduced with immediately satisfactory results.

During 1921-1922, that is to say, while the premium was suppressed, the average consumption of coal per 100 virtual ton-kilometres hauled amounted to 7.86 kgr. (28.33 lb. per 100 virtual ton-miles): it was therefore 50 % above the pre-war figure and those of to-day.

This figure should be sufficient to give an idea of the truly stupendous effort accomplished in restoring the locomotive service to its present condition of order and regularity.

Staff.

The most important task accomplished by the Italian State Railway Administration under the ægis of the Fascist Government has been the reorganisation of the staff.

This duty has been not only technical and economic, but above all, moral, as it was necessary to get the minds of the railway workers back into the old traditional ideas of application and discipline, which had for a time been weakened by subversive propaganda.

At the beginning of the European War the State Railways had a staff of 147 000, or an average of 10.70 men per kilometre (17.22 men per mile) of the system and 38.75 per million axle-kilometres (63.08 men per milion axle-miles) of vehicles hauled.

The lack of discipline in the staff and the irrational application of the 8 hours principle had, as a consequence, a rapid increase in the number of men, so that during the year 1921-1922 the exaggerated figure of 235 000 was reached.

To-day the number has fallen to 167 500, corresponding to an average of 10.15 men per kilometre (16.33 men per mile) and 30 per million axle-kilometres (48.28 men per million axle-miles) of vehicles hauled.

By taking the staff of the different kinds per million axle-kilometres (axle-miles) hauled, the present and pre-war figures can be compared :

STAFF.	Years.			
	1926-1927,		1913-1914,	
	per million of axle-kilometres.	per million of axle-miles.	per million of axle-kilometres.	per million of axle-miles.
Office	3	4.83	4.7	7.56
Station	9.7	15.61	10.6	17.06
Locomotive	4.6	7.40	4.3	6.92
Train	3.3	5.31	3	4.83
Repair shop	4	6.44	4.9	7.89
Permanent way	5.4	8.69	11	17.70

There have therefore been reductions in all classes, other than locomotive and train men. In the case of these men the State Railways Administration has not yet been able to counterbalance by other means the necessary increase caused by

the application of the eight-hour principle, a principle recognised, but rationally applied by the Fascist Government.

As regards station staff, the State Railway Administration hopes to effect other economies by using the train despatching system, which at the present time is used on certain lines only, but which will shortly be in use on about 800 km. (500 miles) more.

The most remarkable reduction of staff has been in the permanent way department. Before the war this department had about 19 000 men, and on this basis, in view of the growth of the system and the application of the eight-hour law, should have been 25 000.

The Administration carefully examined the distribution of the staff on the different lines, and succeeded in reducing the number of platelayers by instituting sectional men who have to inspect each day 8 to 10 km. (5 to 6 miles) of track. Examination of the less important lines on Holidays has been suppressed. The weekly day of rest has been made to coincide with that on which the Inspector goes over his section.

In the case of fixed signals protecting stations, the supervision during the night hours has been reduced, and when they are lighted electrically, it will be suppressed entirely.

Great reductions were effected by reducing the number of level crossing keepers.

From 1920 to to-day, by suitable work on the roads, about 200 level crossings have been suppressed. At the 30 June 1927 there were still 19 672 level crossings on the whole system, of which 3 328 only had keepers. Others, numbering about 3 200, had been fitted with barriers operated from a distance, or with pivoted barriers : 4 460 are looked after by private people, and 8 700 when clearly visible have been opened and the gates removed, warning plates being fitted at a suitable distance from them.

Thanks to these measures, the number of crossing keepers has been reduced to about 6 000.

As regards the permanent way upkeep, improvements have been made in the way the work is done, so that the staff, which was 22 000 before the war and then, owing to the extension of the system, and the eight-hour day, had gradually increased to 30 000, was at the 30 June 1927, 24 000 only.

The Italian Railway Administration in 1925 provided for the revision of the salaries of the staff in view of the increased cost of living, and following an idea of great social importance, that is to say, by improving the conditions of service of the lowest grades to a greater degree than those of the inferior and superior grades of the staff. In this way the pay of each employee, which in 1913-1914 was about 1 950 lires, has become to-day 13 000 in a ratio higher than that of the cost of living.

Nevertheless, if the total cost to-day of the salaries of the staff and charges in connection therewith be compared with the total receipts, it will be found that the ratio is about the same as before the war (44 % instead of 43 %) but is extraordinarily less than in 1921-1922 (75 %). This result is particularly important as the rates on the State Railways have been raised in a lower proportion than the increase in the cost of living.

Finally, it must not be forgotten that the efficient use of the staff is due, not only to the steps taken by the Administration, but also to the diligence and zeal of the staff itself. It will be sufficient to point out that the proportion of staff

absent daily for illness or accident is to-day 2.91 employees, whereas it was 3.32 before the war and 5.27 during 1921.

The Italian railwaymen have a very high idea of their mission and fully understand its importance to the welfare and dignity of the country.

The Minister Ciano has very rightly been able to state that they are to-day soldiers who, reassured by the protection of the Government, work with conscience and discipline, thoroughly convinced that their rights begin where their duty loyally and perfectly accomplished ends.

Rome, April 1928. Year VI.

[624. (01 (.44)]

French regulations for the calculation and the testing of metal bridges.

The French Ministry of Public Works published under the date of 10 May 1927 new regulations for the calculation and testing of metal bridges. We give below some of the most interesting extracts from these regulations. We call attention especially to the new article on the impact allowances for the live loads. The justification for the formulæ is given in the accompanying notes. It should be noted that the formulæ are applicable to both road and railway bridges. We hope at an early date to make a full commentary on these formulæ, comparing them especially with the most recent German formulæ.

Standard gauge railway bridges.

LIVE LOADS. — The live load to be considered in the calculations shall be made up of a standard train formed of two engines and tenders at the head of a rake of loaded wagons.

The dimensions and weights of the engines, tenders and wagons are given in the following table (1).

DESCRIPTION.	Engine.	Tender.	Double bogie loaded wagon.
Total length	10 m. (32 ft. 10 in.).	10 m. (32 ft. 10 in.).	11 m. (36 ft. 1 in.).
Number of axles	5	3	4
Distance between two consecutive axles	1.50 m. (4 ft. 11 in.).	3 m. (9 ft. 10 in)	1.50 m. (4 ft. 11 in.). 5 m. (16 ft. 5 in). 1.50 m. (4 ft. 11 in.).
Distance between a buffer and the nearest axle	2 m. (6 ft. 6 3/4 in.).	2 m. (6 ft. 6 3/4 in.).	1.50 m. (4 ft. 11 inch.).
Load per axle	20 metric tons (19.68 English tons).	20 metric tons (19.68 English tons).	20 metric tons (19.68 English tons).
Total weight	100 metric tons (98.40 English tons).	30 metric tons (29.55 English tons).	80 metric tons (78 72 English tons).
Average weight per metre of length.	10 metric tons (9.84 English tons).	6 metric tons (5.91 English tons).	7.270 metric tons (7.15 English tons).

(1) The locomotive, tender and loaded wagon forming the standard train differ appreciably from the vehicles actually in service on the French railway lines. It has been thought desirable to reserve a certain margin for the future.

For double track bridges, two such trains, running side by side in the same direction are taken into account.

The position, length and make-up of the trains formed with the standard train are to be selected in each case, so as to obtain the maximum stresses in the different parts of the structure. In certain cases, single heading should be considered. The hypothesis of the formation being altered is to be excluded : but if need be, investigations are to be made to see if the presence of empty wagons is likely to produce stresses of greater magnitude than those caused by a train entirely composed of loaded wagons alone. The empty wagons are to be taken in this case as weighing 1 250 kilogrammes per lineal metre (840 lb. per lineal foot).

It is also necessary to substitute for the elements forming the standard train, the engines, tenders and wagons in use, or likely to be in service in the near future on the system, to which the bridge to be built belongs, in the case in which this substitution results in an increase in the stresses carried by the different parts of the structure.

Note is to be taken of the dynamic effects of shocks from the live loads and the speed at which they act by increasing the weights of the axles of the standard train adopted in the calculations. The co-efficient of increase applicable to a part of the flooring, to a girder, or to a bay of a girder, is given by the formula :

$$1 + \alpha + \beta = 1 + \frac{0.4}{1 + 0.2\,L} + \frac{0.6}{1 + 4\frac{P}{S}}$$

in which L = the length, expressed in metres, of this part of the flooring, of the girder, or of this bay of a girder; P the total permanent load carried by it including its own weight; S the maximum weight of the live load it may be called upon to carry.

Stresses in the metal. — The principal stresses in each piece or section of the metal frame work are to be calculated.

If the main girders are triangulated, it is obligatory to calculate the supplementary loads that can result therein from any defective arrangement of parts of any kind such as, especially, lack of symmetry of the bars in relation to the centre plane of the girder and the eccentric loading resulting therefrom.

As regards the additional loading due to the rigidity of attachment of the bars to the boom, or to lack of convergence of the centre lines of the parts on the centre plane of the girder, it is desirable, if not directly calculated and if not outside the ordinary arrangements in use, to take them into account by increasing the principal stresses by one-tenth.

As regards details of the bridges, in calculating them allowance should be made for any partial boxing in that may possibly occur at their ends.

After having made these various calculations, the values of the stress in the metal expressed in kilogrammes per square millimetre is to be determined in conformity with the principles of the strength of materials. The following notation is to be used for any one part of the structure and the same type of stress :

c represents the stress under dead load;

d represents the stress under the increased live load;

v represents the stress under wind at 150 kgr. per m² (30.72 lb. per square foot);

w represents the stress under wind at 250 kgr. per m² (51.20 lb. per square foot);

t represents the stress under the action of the temperature.

PARTS IN COMPRESSION. — Each part in compression is to be checked in addition to make sure that it is not subject to bending.

The method engineers are to follow is not prescribed. The following indications may be found useful :

Let l be the length of the part in compression;

r be its minimum radius of gyration;

E be the co-efficient of elasticity of the metal taken lengthwise;

N its limit of elasticity;

R its breaking strength in compression;

R_1 its permissible working stress, these last four being expressed in kilogrammes per square millimetre.

The critical stress of Euler expressed in the same units will be given by :

$$C = m\pi^2 E \frac{r^2}{l^2}$$

in which m is a numerical constant depending on the method of fastening the part at its two ends, some usual values being :

$m = 1$ for a part jointed at both ends;

$m = 4$ for a part boxed in at both ends;

$m = 2$ for a part partly boxed in at both ends;

$m = 2$ for a part jointed at one end and completely boxed in at the other;

$m = 1/4$ for a part boxed in at one end and free at the other (mast).

This stated, the simple compression stress $\frac{F}{S}$ calculated on the gross area S should meet the following conditions :

A. — When referring to Euler's theory, three cases are to be noted :

1. If $C < N$, the inequality to be checked is :

$$\frac{F}{S} \leqslant C \times \frac{R_1}{R};$$

2. If $N < C < 3R - 2N$, the inequality to be checked is :

$$\frac{F}{S} \leqslant \frac{C + 2N}{3} \times \frac{R_1}{R};$$

3. If $3R - 2N < C$, the inequality to be checked becomes reduced to $\frac{F}{S} \leqslant R_1$.

(It will always be covered if the part is suitably calculated in other ways : in other words, it is admitted that there is then no tendency to premature failure through eccentric loading.)

B. — When one uses Rankine's formula, the inequality to be checked will be for all values of C :

$$\frac{F}{S}\left(1 + \frac{N}{C}\right) \leqslant R_1.$$

Proof of stability.

CONDITIONS OF STABILITY. — The structure shall be considered as stable from the point of view of elastic equilibrium or of the stress of the metal if the values of the stress considered in articles 8 and

10 satisfy the conditions expressed by the following unequal quantities:

1. $c + d + t \leqslant R_1$;
2. $c + d + t + v \leqslant R_2$;
3. $c + t + w \leqslant R_2$.

The letters R_1 and R_2 designate the limits of safety or allowable working stresses; these limits depend:

1. on the kind and quality of the metal used;

2. on the sort of stress considered: tension, compression, slip or shear.

The most usual of such stresses are defined in the following articles:

Rolled or cast steel. — The safe limits are to be taken as follows:

1. Tension or compression:

$R_1 = 13$ kgr.
(8.26 English tons per square inch);
$R_2 = 14$ kgr.
(8.89 English tons per square inch);

2. Slip or shear:

$R_1 = 10$ kgr.
(6.35 English tons per square inch);
$R_2 = 11.2$ kgr.
(7.11 English tons per square inch).

Rivets. — The safe limits are to be taken as follows:

1. Shear: $R_1 = 9$ kgr. (5.72 English tons per square inch); $R_2 = 10$ kgr. (6.35 English tons per square inch);

2. Tension or resistance of the heads to pulling off: $R_1 = R_2 = 2.5$ kgr. (1.59 English tons per square inch).

When a builder can prove that all the rivets in a unit have been closed by mechanical pressure riveters, the safe limits may be increased for this reason alone by 1 kgr. (1 420 lb. per square inch) as regards shear, and 0.5 kgr. (710 lb. per square inch) as regards tension.

The stress of the rivets in tension is to be calculated if necessary to prove the stability of the assembled parts.

No proof will be required of the strength of rivets which are used only in accordance with the usual practice when building bridges. Such rivets are those used to rivet together a number of plates or the rivets along the edges.

* * *

The following table from the Specification of the Ministry of Public Works, dated 29 October 1913, gives the minimum tensile strength and elongation required in the case of rolled material.

The extension at breaking is measured on a gauge length:

$$L = \sqrt{66\ 67\ S},$$

in which S is the cross sectional area of the test piece.

DESCRIPTION OF THE MATERIAL.	Load in kilograms per mm² (in English tons per square inch) of the original area.		Extension at fracture measured between gauge points.
	At the elastic limit.	At fracture.	
Rolled steel sections, flat plates, flats and round, square or profiled bars.	21 (15.24)	42 (26.67)	25 %
Rivets	20 (12.70)	38 (24.13)	28 %

Railway bridges for metre gauge lines.

The *standard train* used in making the calculations is given in the following table :

DESCRIPTION.	Tank engine.	Loaded wagon.
Total length	10 m. (32 ft. 10 in.).	8 m. (26 ft. 3 in.).
Number of axles	5	5
Distance between two consecutive axles	1.50 m. (4 ft. 11 in.).	4 m. (13 ft. 1 1/2 in.).
Distance from a buffer to the nearest axle	2 m. (6 ft. 6 3/4 in.).	2 m. (6 ft. 6 3/4 in.).
Axle load	10 t. (9.84 English tons).	20 t. (19.68 English tons).
Total weight	50 t. (49.20 English tons).	20 t. (19.68 English tons).
Average weight per metre of length	5 t. (4.92 English tons).	2.5 t. (2.46 English tons).

« If the empty wagons have to be formed in the train, their weight shall be reduced to 750 kgr. per lineal metre (504 lb. per lineal foot). »

« When it is a question of a bridge to be built to carry a light railway or a tramway, any departures required to be authorised in view of the traffic expected, of the method of traction to be used, and of the actual weight of the rolling stock, shall be subject to the special authorisation of the Ministry for Public Works. »

Road-bridges.

LIVE LOADS. — Two systems of live loading are to be considered :

A. — The roadway to carry a uniformly distributed live load reaching per square metre the value p given by the formula :

$$p = 820 \text{ kgr.} - 4 \text{ L.}$$

in which L is the span of the bay in metres or by the formula :

$$p = 500 \text{ kgr. if L} > 80 \text{ m.}$$

The footpaths to be able to carry a uniformly distributed live load of 400 kgr. per m² (81.93 lb. per square foot).

The length of the loaded areas is to be chosen in each case so as to obtain the maximum stresses in the various parts of the structure.

B. — On the roadway for the above live load are to be substituted standard trains, each composed of two four-wheeled lorries having the following characteristics :

Total weight	16 t. (15.76 English tons).
Rear axle weight	12 t. (11.82 — —).
Front axle weight	4 t. (3.94 — —).
Overall length	10 m. (32 ft. 10 in.).
Overall width	2.50 m. (8 ft. 2 1/2 in.).
Distance between axles.	4 m. (13 ft. 1 1/2 in.).
Distance apart of the wheels on an axle	1.70 m. (5 ft. 7 in.).
Width of wheel rim	0.30 m. (11 13/16 in.).

It is to be supposed that there will be as many standard road trains running side by side in the same direction as the width of the road will allow, these road trains being placed in the most unfavour-

able position for the part under consideration.

The co-efficient of dynamic impact shall be calculated in accordance with the formula given above.

The Minister of Public Works reserves the right to authorise departures from this programme of live loads, either to make it more stringent as in cases where vehicles of exceptional weight, either civil or military, have to pass, or to make it easier when the kind of traffic and the service to be covered by the structure justify any such measure.

General considerations attached.

Allowance for the dynamic effects of moving live loads.

The Commission appointed to draw up the 1915 Regulation (Mr. Mocquery, President; Mr. Jean Résal, Secretary, took as one of its principal references the introduction of the idea of the dynamic effects of moving live loads. It considered as a fact incontestably proved by experiment, that a train or convoy running over a bridge stressed the parts of the bridge more than the same train or convoy would when standing. The report stated that by recording with automatic instruments the vibratory movements set up by the passage of the train at speed, it had been made possilbe to measure the dynamic increase in the stress. It shewed also that it had been found that this dynamic increase could attain 70 % in the girders and cross bearers under the rails, that it diminished rapidly as the span of the girder considered increased and became almost negligible for large spans. This it stated is a fact established by theory and proved by observation.

An even more definite statement will be found in the Commission's report. If c be the stresses due to the dead load, d that due to the moving live loads, it proposed to increase d by a coefficient $(1 + \alpha)$ given by the lineal equation :

$$1 + \alpha = 1.733 - 0.3067 \frac{c}{d}$$

with a correction so as never to obtain : $1 + \alpha < 1$.

It should be noticed that c, d and consequently α relate to a particular element of the structure, and that they even vary for a given element, with the section investigated, and even with the kind of stress studied (tension, compression, shear).

In view of such definite statements, how did this Commission remain completely silent on this question of the impact allowance in the text it elaborated and which became the Regulation of the 8 January 1915 ? Why, instead of putting forward a multiplicator such as $(1 + \alpha)$ that is to say, greater than unity for the stresses d due to the live loads, did it take the opposite side in reducing the stress c due to the dead load of which only 4 or 6 tenths, according to the case, were taken ? It was no doubt to prevent upsetting existing practices and so as not to shew in the calculations working stresses considerably higher than those then in use, which up to that time had not exceeded 8 kgr. (5.08 English tons per square inch) for ordinary rolled steel. None the less, the Report of the Commission was very definite on the allowable limit for the fatigue stress which after much consideration it fixed at 13 kgr. (8.26 English tons per square inch) for rolled steel. Furthermore, there is no doubt that it appeared to it to be reasonable to raise the calculated working stress as new factors, such as the impact allowance, up to then ignored, were introduced.

It is certainly not the idea of the present Commission to criticise the work of its predecessor whose initiative has had satisfactory results. But it had to give some explanation on this subject to explain the real origin of the complaint of the builders of metal bridges. For these latter, the impact allowances have to be applied, although they are implied only, and it is not easy to see if the raising of the calculated working stresses has always taken it into account sufficiently and equitably. In the case of bridges in reinforced concrete, it is still completely ignored.

The method devised in 1915 had also in addition to its lack of clearness some other defects. The checking of the numerous unequal quantities put forward in article 11 of the Regulation appeared too complicated and defeated the designing offices, whether rightly or wrongly, complaints arising even from some engineers of the Bridges and Roads Department. The real complication was not so much in the actual carrying out of a given check as in the use of the continually varying factor $\frac{c}{d}$ when passing from one check to another.

For these reasons, the present Commission, after having at first simply endeavoured to amend the application of the ideas which were accepted in 1915, had to reopen again the discussion relating to the determination of a suitable co-efficient of majoration, and to select from amongst the very varied causes which come into play to aggravate or extenuate the dynamic effect of the moving loads, those which seemed to be really preponderating, and which for lack of better, are the only ones to retain. This analysis has been amply discussed and was the subject of many enquiries which it would be wearisome to recall here. It will be sufficient to give the reasons why the factor $\frac{c}{d}$ which was energetically opposed by the interested parties, builders and representatives of the Railways, as well as by some members of the Commission was finally given up.

When the reason for the choice which had been made of $\frac{c}{d}$ to build up the dynamic effects of the live loads is looked for, it is possible to find scarcely more than a parallelism of fact between this factor and the span of the bridges or girders. Résal satisfied himself by stating that the ration $\frac{c}{d}$ varies in railway bridges roughly as the span, and that it is consequently logical to vary the factor of majoration $(1 + \alpha)$ from the maximum value 1.73 applicable to the small bridges for which $\frac{c}{d}$ is near zero, up to a value near unity, applicable to girders of large span, and therefore heavy, in which the ratio $\frac{c}{d}$ becomes high.

But if this rather vague explanation is not accepted, and if we ask why a given part subjected to variable stresses, between a lower limit c and an upper $c + d$, is less tried than a similar part initially not under tension and subjected to the same variation of stress, no satisfactory explanation can really be found. For equal value under shock, the value represented in fact by the limit d of the maximum efforts, it would seem on the contrary, that the piece less stressed in the initial position ought to be the better able to stand up under load. During consecutive oscillations under shock, the initial tension taken as constant, does not ac-

complish, it is true, any work; but during the first half oscillation it has to do work of the same sign as the added tension (c and d being of the same kind and of the same sign by hypothesis) and consequently the first extension, as well as the stresses within the elastic limit, ought to be increased thereby.

It has sometimes been said that the use of the ratio $\frac{c}{d}$ has been found a practical method and, as it were, automatic, it being more difficult for parts subjected to alternating stresses, as for such pieces c is very small if not nil, and the maximum co-efficient of majoration is applied thereto. This result is of course interesting. But it can be remarked that to be logical, for the ratio $\frac{c}{d}$ of the extreme stresses of the same sign, the ratio $\frac{d'}{d}$ of the extreme stresses of opposite sign should be substituted.

It can also be said that some tests, such as those of Woehler, on the effect of the variable stresses have led to a limitation of the maximum allowable stress as a function of the ratio of the extreme stresses. To that it can be replied that the tests of Woehler did not introduce the idea of shock, nor consequently of dynamic effects, although this may have been by error; that further no one has even obtained premature breakages, at least for the mild steel in ordinary use, so long as the maximum stress does not exceed the elastic limit, which is certainly the case as regards bridges : finally, that it has been definitely shewn that extreme stresses of opposite sign have to be taken into account, parts subjected to alternating stresses breaking quicker than the others.

Finally, the ratio $\frac{c}{d}$ is not used in any theory on the shock of solid bodies.

The Commission considering, furthermore, the difficulties of application pointed out above, then felt itself obliged to abandon the use of this ratio, and to look for something to take its place. The Commission felt obliged to state first of all that it appeared to it to be impossible to pretend that a real evaluation of the dynamic efforts of the moving loads could be made. There are too many causes, that is to say, too many independent variables which come into action in such complex phenomena : kind of moving loads, speed at which they act, kind and state of repair of the track, kind of parts considered, their connections with other parts, etc. It is therefore advisable to make the regulations simpler, and to be satisfied with approximations, provided these be rational and within the known experimental limits.

As regards these limits, the Commission agrees that the co-efficient of majoration can vary between 1 and 2. The higher limit is above the 1.73 found as a result of the tests made on railway bridges which the 1915 Commission accepted. It considered that these (recording the static deflections and the vibratory deflections) only applied to the main girders of the structures and not to parts of the flooring. For this latter, the requirements should be more severe, and as a matter of fact the 1915 Commission had itself increased the co-efficient of majoration to be applied thereto approximately to 2 by introducing the fact of wheels and axles out of gauge, or exceptional vehicles.

Furthermore, it took into account the results for the whole structure as given by the theory of shocks on prismatic parts

which, as is known, were the object of noteworthy investigations during the last century, and to which the names of Young, Navier, Saint-Venant, Boussinesq, Phillips, Henri Résal, Bresse, Willis and Stokes, to mention only the best known, are attached. More recently Jean Résal, without pretending to deal with the whole of the problem, has dealt with many well chosen points in his *Traité de ponts métalliques* (vol II).

All these theories, in spite of the very different points of view from which they were approached, end in the same result, which can be summed up as follows :

When instantaneous shocks alone are considered, we can, as a first approximation, limit ourselves to correcting the elastic deformations due to the live loads by multiplying them by an expression of the form

$$\frac{2}{1 + K\frac{P}{S}},$$

always less than 2, P being the mass supporting the shock, and S that causing it.

There is even a valuable experimental confirmation of this point, Hodgkinson and Tredgold having decided to see if the dynamic deflection of bars subjected to sudden shocks could really reach double that of the static deflection, as certain investigators had obtained as a first approximation. Their tests shewed that it was not so, and that the facts observed would be satisfied by introducing a factor of reduction of the form $\frac{S}{P + S,}$ which would confirm the argument given above.

When we consider, not instantaneous shocks, but live loads which act over a time much longer than the proper period of oscillation of the part, it then becomes necessary to reduce the value of the correction very appreciably. At the limit we can well imagine that we should consider not the total live load S, but only the fraction of this live load which can come into action during the course of the first half period. The fraction acting during the next half period cancels out, or nearly so, the effect of the first, and so on. Broadly speaking, this is what happens in the case of bridges. Résal has shewn that for a girder of 100 m. (328 feet) span run over by a train at 120 km. (75 miles) an hour, the time of application of the load is at least four times the period of vibration. For a girder of 36 m. (118 feet) span, the ratio would still be about three times. For a longitudinal member 4 m. (13 ft. 1 1/2 in.) long, the ratio would be no more than 1.33.

Several other points have to be considered.

When a part is connected to others, or to bearings elastically free to yield, the oscillations thereof damp out very quickly, much more quickly than in a part free to move. There is a change of energy in the part, and a transmission of energy to the adjacent parts. The first part acts as regards the other the role of a damping device.

When a part forms an integral part of a complex system, its own period of oscillation becomes masked by that of the whole system.

Two principal points emerge from the above. On the one hand it is necessary to take into account the way in which the live load acts, and especially the speed at which it acts in comparison with the period of vibration.

On the other hand, the ratio of the masses causing the shocks to those receiving them must be considered.

In order to take the former into account, the Commission first of all thought of making a clear distinction between the main girders of a bridge and the parts of its floor, which latter are usually under dissimilar conditions as regards the closeness of the shocks and the speed at which the live loads act. However, on small span bridges, the difference largely disappears. In the end the Commission thought that the principal dimension was simply the length, either of the part of the bridge, or of the girder. At equal speeds of trains or stock, it is true that on this length alone depends in fact the relative speed at which the bridge is loaded. One of the members of the Commission, Mr. Godard, had pointed out that it was as a function of the « length » that the rules for correcting the figures used in certain foreign countries, and notably in England and the United States, were got out. It should also be remembered that the builders also had formerly suggested that the regulation should be based on the length of the girders. The refusal to do so was justified at that time when only this overall measurement was in consideration : there is no reason to maintain the refusal if alongside this measurement, others are brought in, taking into account elements that have been neglected, and especially the ratio between the masses giving rise to the shocks and those supporting them in order to meet the second requirement given above.

In the end, the Commission proposed to include in the co-efficient of majoration at the same time the two following main measurements :

L, length of the part, or of the girder, $\frac{P}{S}$, ratio of the dead weight P carried to the live load S that it may have to carry. The formula would have the form :

$$1+\alpha+\beta=1+\frac{0.4}{1+0.2\,L}+\frac{0.6}{1+4\frac{P}{S}}.$$

For a very short and very light part, L and $\frac{P}{S}$ being negligible, the co-efficient of majoration could attain a theoretical value of 2.

For a main girder of 100 m. (328 feet) span, supposing a value of $\frac{P}{S}$ equal to unity, the co-efficient would fall to about 1.14. The hyperbolic form given to each of the factors α and β assure at once a high value for the short and light parts which falls relatively quickly for relatively important and heavily loaded parts. This is the result desired.

It is true it would be possible to go further in the direction of greater precision by separating, for example, the bridges into different classes, according as it is a question of railway bridges for example, or road bridges, or of ballasted or non-ballasted railway bridges. In this way we should have taken into account the factor of the « elastic bed » by using distinct formulæ with different co-efficients for each of these kinds of bridges. The Commission felt it would not follow this line of argument, no doubt thinking that on the one hand it was vain to pretend to anything more than approximations, at least during the absence of more definite experimental documentation, and considering on the other, that in the proposed formula the term β, bringing in the ratio between the loads and live loads, had already taken into account to a sufficient extent the varied conditions of layout of railways

and roads. Furthermore, as regards road bridges, in the case of which one might be tempted to make certain reductions on account of the lower speed of the traffic and the less likelihood of the full live load occurring, the Commission thought that these considerations were in fact counterbalanced by the state of the roads, by the possible increase in shocks resulting therefrom in certain cases, and by the prevailing uncertainty as regards the weight of the vehicles which can use these structures.

In spite of the length of this statement, the Commission felt obliged to answer in advance a possible objection to the adoption of an uniform co-efficient of majoration for all the parts forming a complicated built-up girder, a trellis girder, for example. For a given diagonal, it is not the total live load which causes the greatest stresses. Ought we not to take for the diagonal in question the partial live load S′ corresponding thereto, and to substitute it for the total live load S applicable to other stresses ? Without mentioning the complication which would result therefrom — as it would be necessary to have as many different co-efficients as there were diagonals — the Commission points out that it has already met this objection when speaking earlier on of the periods of oscillation of the complex systems themselves, and adds this last reason which to it appears convincing. At the same time that the partial live load S′ is causing the greatest stresses, it is quite rational to take into consideration the complementary live load $S'' = S - S'$, which then produces stresses in opposition, and of which the disappearance gives rise subsequently to stresses of the same sign as the introduction of the partial live load S′. The oscillation, or the range of the extreme stresses on which the dynamic efforts ought to depend, therefore brings into action the total live load, as well as the weight of the structure. The same thing occurs in all other analogous cases.

Making use of the quantities L and $\frac{P}{S}$ has obviously the advantage of simplicity. In addition, it has a very valuable secondary merit. It makes it possible to calculate the co-efficient of majoration applicable to any particular case before any stress calculation is made, and consequently the majoration can be applied to the live loads themselves, as well as to the stresses resulting therefrom. It is for this reason that the new rule drawn up is to be found in the new Regulations in article 2, which deals with live loads.

Another advantage which follows directly is that we can at once apply to bridges in reinforced concrete the rules for the majoration which should be applied to steel bridges without being disturbed by the differences which are obtained as a result of the special methods of calculation for reinforced concrete structures, to which Hooke's law is not always applicable. From the moment the majoration applies to the live loads themselves, there is no reason why it should not be introduced into the subsequent calculations, whatever they be.

Railway bridges carrying standard gauge lines.

Adoption of a new standard train (art. 2). — The chief Railway Companies asked that advantage be taken of the redrafting of the 1915 Regulation to substitute for the 40-t. (39.36 English tons) wagons on two axles the much heavier wagon weighing 80 t. (78.72 English tons) on four axles. The weight per axle re-

mains unchanged, but the distribution of the axle is different, as is the weight of the wagons per metre run, which has increased from 5 to about 7.36 t. (1.50 to 2.21 English tons) per foot run. This request was favourably reported on by the Control Service, and the Commission also received it with favour.

The Railway Systems also asked, in the case of bridges on lines open to international traffic, for the adoption of the standard rake of wagons derived from the preceding one by a simple majoration of 1/10 of all the axles. Their individual weight would be increased from 20 to 22 tons (19.68 to 21.65 English tons). The Commission felt unable to accept this request which raised the grave question of the definition of the lines open to international traffic. It considered that for these lines, as for all others, liable to have to carry special traffic, it was always permissible for the Railway Systems to put forward proposals for a heavier standard rake. In order that there should be no mis-understanding on this matter, it has laid down that we can substitute for the standard train defined by the Regulation another standard train composed of the heaviest units in service or likely to be in the near future.

The other alterations made to article 2 are simply editorial changes.

Fatigue of the metal (art. 8). — The Commission has introduced into this article two alterations which it considers important.

1. *Calculation of the stresses due to the dissymmetrical joints of trellis work.* — The first deals with certain loadings which occur in the bars of the trellis work of the girders when these bars are not so arranged as to form a symmetrical system in relation to the mean plan. This arrangement is to be avoided as far as possible as there usually results from the eccentricity of the fastenings fairly high bending moments, which can much increase the stresses in the parts. This eccentricity, when it is a question of isolated angles or U bars, can become sufficient to cause reversal of the principal stresses: a tensile stress, for example, being found at the edge of the flanges of a U bar, the back of which is under compression. Bridges are known in which all the trellis bars are bent. It is therefore necessary to separate such stresses from those given the name of « secondary stresses » and which the 1915 Regulation did not require to be calculated, a fixed plus allowance of 1/10 being allowed. The Commission requires these secondary stresses to be calculated.

Interested quarters have protested against the strictness of this new arrangement owing to the difficulty of making the calculations involved. They agree that the allowance of 1/10 for the secondary stresses was insufficient in this case, and offered a new fixed allowance of 1/10 in addition to the first 1/10 in this case of dissymmetrical trellis work. They consider that this new majoration would be amply sufficient, and give as their reason therefor the fact that many bridges have trellis girders so formed and have however stood up well.

The Commission has retained its proposal. It does not disprove the statement that many bridges and dissymmetrical trellis work have been put into service without any accident having occurred. Certain of these bridges, however, have vertical uprights, or even rigid wind-bracing — others had the trellis bars so close together that any deflection due to twisting was transmitted to the webs throughout their whole length — others again

were able to behave as simple trellis girders but were fitted with counter bracing bars in view of the reversal of loads. However this may be, if by care the builders have been able to avoid serious accidents in the past, it is none the less necessary to make engineers and builders realise that there is danger in this arrangement which, whilst it cannot be completely prohibited, must be strongly discountenanced. The obligation of supplying reasons for its use will in itself act as a brake and be of assistance.

The Commission also does not contest the fact that exact calculations would often be very difficult and sometimes of no interest. In order to shew it only requires practical calculations, it proposes to insert in the Commentaries the necessary indications to enable them to be made quickly and with sufficient accuracy. It is above all a question of requiring engineers and builders to take account of the order of magnitude of the possible secondary stresses.

2. *Calculation of the shearing moment at the ends of the floor members.* — The longitudinals and stretchers usually have full webs and are very often of constant section. It has often been thought unnecessary in their case to make any calculations other than those concerning their fatigue under bending at the centre and their shear stress at the ends, furthermore carrying out the calculations as though these parts were simply supported at their two ends. In practice this latter theory is far from being realised, as frequently the ends are rigidly connected up in an end assembly. It is true it gives additionnal safety as regards the bending stress in the central area, but it is not so as regards the area near the ends where, owing to the rigid connections which act as though the ends were partially built in, negative bending moments, comparable in value to the positive bending moments at the central area, arise. It is therefore often an error of design to use variable sections which diminish too rapidly towards the ends. The rigidity and good behaviour of the structure also suffer as a result, and the saving of metal obtained in this way is not always very well chosen. The Commission considers it preferable to persuade Engineers to distribute the steel to better advantage by frankly admitting and taking into account the partial encastering moment, which always occurs, so as to save a little metal in the central area, and not to carry the saving too far when the ends are being considered. Such is the object aimed at by the text of the Rules and made clearer by the Commentaries on the most usual cases met with.

We know, of course that the connections of the parts of the flooring have been found in many cases to be the weak points of the structures. Slipping or even breakages of rivets have also been fairly frequently noted, principally in railway bridges. This question is dealt with in article 10 of the Regulations. As this is closely connected with the preceding one, it will be more simple to discuss it at once. The defects of these connections is largely due to the practice of treating these parts as being simply supported at their ends. In fact, according to this hypothesis, there is nothing to do but check the joints as regards shearing stress and the shear of the rivets. By requiring any encastering moments which may occur to be taken into account, the Commission shews thereby that it is also desirable to see if the joints are properly designed so that the rivets in the top part can carry without being over-stressed the

tensile stresses that may develop therein. This check will frequently result in a different design being adopted, as, for example, the use of junction gusset plates, or even to substituting in place of certain rivets, bolts better able to stand the calculated tensile stresses. Desirable and practical improvements can be made as regards this point.

Parts under compression (art. 9). — Article 9 of the 1915 Regulation, dealing with the buckling of parts in compression, had considerably limited the judgment of the Engineers and Builders by imposing a certain method of checking, that known as « Rankine's rule ».

This was contrary to the general principle, repeated in Article 6, that the Government did not lay down any particular method of calculation, and gave rise to many protests which were the louder as the question of buckling has been, and is, the subject of violent controversy.

In addition, by imposing Rankine's rule, and adding the remark that the calculations should take into account the net section of the parts, a certain confusion has been caused as to the actual meaning of this rule. It is here a question in fact, not of imposing a new majoration of the calculated loads, an increase which would be super-imposed on those of article 2 or on those article 8 requires, but simply of making a check to ascertain if, outside all questions of fatigue, the total compression load of the part is sufficiently wide of the critical buckling load, known as Euler's critical load, which cannot be exceeded without danger, no matter how well the part has been made, nor how well centred under the compression load.

What the Commission proposes is to return in the text itself of the Regulation to the less restrictive requirements of the 1891 Regulations, and to restore to the Engineers their freedom.

Moreover, at the request of interested circles, the Commission has added in the Commentaries the necessary information to enable one or other of the two principal methods suggested to be applied quickly, without however excluding others. The rules shewn for the two methods mentioned are, furthermore, in as close as possible agreement one with the other.

R. D.

[624. (01 (.43)]

The German regulations for the calculation of metal road bridges.

We give below some interesting extracts taken from the review *Der Bauingenieur* of the 21 May 1927 — « die Baunormung » — from the standard German regulations on the calculation of road bridges. We call attention especially to the introduction into this new regulation of the coefficient of dynamic increase (impact) until now only used for railway bridges. This regulation is based, moreover, to a large extent, on the regulation of the German railway bridges — value of the maximum stress — coefficients for the calculation of parts loaded vertically, checking the stability of open bridges, etc.

Values of E, G for the different qualities of constructional steel.

E = Modulus of elasticity, tension and compression in kgr. per cm² (in lb. per square inch).
G = Modulus of elasticity, shear, in kgr. per cm² (in lb. per square inch).

	E	G
Hammered iron	2 000 000 (28 400 000)	770 000 (11 000 000)
Mild steel St. 37	2 100 000 (29 900 000)	810 000 (11 500 000)
Mild steel high tensile :		
St 48	2 100 000 (29 900 000)	810 000 (11 500 000)
St Si	2 100 000 (29 900 000)	810 000 (11 500 000)
Cast steel	2 150 000 (30 600 000)	830 000 (11 800 000)
Forged steel	...	...
Supports	2 100 000 (29 900 000)	810 000 (11 500 000)
Cast iron	1 000 000 (14 200 000)	830 000 (11 800 000)

Dynamic coefficient.

The moments, shearing forces, and stresses in the bars through moving loads, ought to be multiplied by a dynamic coefficient φ depending upon the span. For parts of the flooring, stringers and transverse girders, the span to be considered is the effective span of these parts. For the main girders carried on two supports, the span to consider is the length between the supports. In the case of continuous girders, the span of the bay is taken into account for each bay : for the elements in stress on bearings the dynamic coefficient is calculated by taking the arithmetic mean of the spans of the adjacent bays.

In the case of double track bridges the coefficient to be used will correspond to 1 1/2 times the span of the bay : if there

are three or more tracks, it will be calculated on the supposition of a span of double length.

The moving load corresponding to a crowd on a foot-path or foot-bridge is not subjected to the dynamic exaggeration : an exception is made to this rule in the case of a crowd on the side borders of the roadway.

This coefficient is not taken into account when calculating the thrust of the earthwork.

Table of the values of the dynamic coefficient φ according to the span.

Span in metres (in feet and inches).	L	5 (16′ 5″)	10 (32′ 10″)	20 (65′ 8″)	30 (98′ 5″)	40 (131′ 3″)	50 (164′)	60 (196′ 10″)	70 (229′ 8″)	80 (262′ 6″)	90 (295′ 4″)	100 (328′ 1″)
	φ	1.4	1.39	1.37	1.36	1.34	1.33	1.32	1.30	1.28	1.27	1.25
Span in metres (in feet and inches).	L	110 (360′ 11″)	120 (393′ 8″)	130 (426′ 6″)	140 (459′ 4″)	150 (492′ 2″)	160 (524′ 11″)	170 (557′ 9″)	180 (590′ 7″)	190 (623′ 4″)	200 (656′ 2″)	
	φ	1.24	1.22	1.21	1.19	1.18	1.16	1.15	1.13	1.12	1.1	

Calculation of the stresses and of the permissible limiting stresses.

The *main stresses* are those due to the dead load, to the moving load and to temperature effects.

The *total stresses*, are those obtained by adding to those above the stresses due to wind, friction at the bearings, and to the bearings being out of line.

The *secondary stresses* due to the rigidity of the fastenings of the bars in the trellis girders and equally to the rigidity of the joints, stringers, cross girders and of cross girders main girders, should not be calculated.

In the case of their being calculated, the limiting stresses should be ascertained.

Limiting working stresses allowable.

These stresses are limited in comparison with those allowed for constructional steel St 37 having 2 400 kgr. (34 120 lb. per square inch) as the apparent limit of elasticity.

For steel of other quality having σ_s as limit of elasticity, the limiting working stress allowed should be that of steel St 37 $\times \frac{\sigma_s}{2\,400}$.

Permissible maximum stresses allowed in tension and bending.

	Principal stresses, in kilograms per cm² (in lb. per square inch).	Total stresses, in kilograms per cm² (in lb. per square inch).
St 37	1 400 (19 900)	1 600 (22 800)
St 48	1 820 (25 890)	2 080 (29 580)
St Si	2 100 (29 900)	2 400 (34 120)

Permissible stress in shear = 0.8 of the above stresses.

Open bridges.

In the case of trellis bridges without overhead wind bracing, the open transverse frame, verticals, and stretchers will be calculated as having to resist the two transverse forces acting towards the interior or towards the exterior at the level of the booms in compression and equal to the 1/100th of the stress of the adjacent element of the boom in compression most highly stressed.

In the case in which a diagonal element of the trellis in compression should be held up by a secondary member provided for the purpose, it should be calculated

under a transverse thrust equal to 1/100th of the stress along the compression axis of the bar.

Calculation of the wind bracing.

The maximum allowable unit stress is 1 200 kgr. (17 060 lb.) for St 37, 1 560 kgr. (22 200 lb.) for St 48 and 1 800 kgr. (25 600 lb.) for St Si.

Calculation of the supports.

In calculating the bearings, the increase of the dynamic coefficient for moving loads should be taken into account.

Maximum allowable stresses when calculating the bearings.

KIND OF METAL.	Principal stresses.		Total stresses.	
	Bending, in kgr. per cm² (in lb. per square inch).	Compression, in kgr. per cm² (in lb. per square inch).	Bending, in kgr. per cm² (in lb. per square inch).	Compression, in kgr. per cm² (in lb. per square inch).
Cast iron	Tension..... 450 (6 400) Compression. 900 (12 800)	1 000 (14 200)	Tension..... 500 (7 100) Compression. 1 000 (14 200)	1 100 (15 600)
Cast steel. . . .	1 800 (25 600)	1 800 (25 600)	2 000 (28 400)	2 000 (28 400)
Forged steel . .	2 000 (28 400)	2 000 (28 400)	2 200 (31 200)	2 200 (31 200)

The allowable stresses in compression in the details of these bearings, in which the area of contact is theoretically a point or a line, are the following :

Cast iron :
5 000 kgr. per cm² (71 000 lb. per sq. inch).

Steel St 37 :
6 500 kgr. per cm² (92 400 lb. per sq. inch).

Cast steel :
8 500 kgr. per cm² (120 900 lb. per sq inch).

Forged steel :
9 500 kgr. per cm² 135 100 lb. per sq. inch)

under the loads considered when determining the main stresses. For the whole of the loading (total stresses) these limits become 6 000, 8 000, 10 000 and 12 000 kgr. per cm² (85 300, 113 800, 142 000 and 170 600 lb. per square inch).

In the moveable appliances with several rollers, these unit loads should be reduced by 1 000 kgr. per cm² (14 200 lb. per square inch).

In the bolts or pins of joints, the maximum allowable compression stress of the pin is 1.3 times the maximum allowable tensile or bending stress.

Allowable stresses on the bearing blocks in stone or concrete and on the masonry lying under the bearing plates

1. On the seat when in cement-mortar half and half or on the lead packing sheet 50 kgr. per cm² (710 lb. per square inch).

2. On the seat of the stone bearing block on the masonry below it :

Concrete (1/3/5) :
25 kgr. per cm² (355 lb. per square inch).

Ordinary masonry :
12 kgr. per cm² (170.6 lb. per square inch).

3. Allowable bending or shearing stress of the granite or hard stone bearing block : 15 kgr. per cm² (210 lb. per square inch).

Allowable stresses in constructional timber.

Log. *Kind of timber.*	Allowable stresses.	
	Bending, in kgr. per cm² (in lb. per square inch).	Compression in kgr. per cm² (in lb. per square inch).
Ordinary pine. . .	90 (1 280)	15 (210)
Oak.	110 (1 560)	35 (500)

R. DESPRETS.

[628 .11]

Simplified methods in the preparation of schemes for roads and railways,

By Domenico RUGGERI,
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Figs. 1 and 2, p. 852.

(*L'Ingegnere*, February 1928.)

The author proposes to lay out vertically the cross sections at the intermediate points on the longitudinal profile. By joining up by straight lines the outside points of intersection of the cross sections, the corrected horizontal projection of the surface occupied by the road itself to the scale of the cross section for height, and to that of the longitudinal profile for lengths is obtained. By graphically integrating these projections by intervals, the areas of the land occupied are arrived at, and in the same way the design of the cross sections, the calculation and estimates for the land occupied can also be collected together on the same sheet of paper.

The author then goes on to propose for the calculation of the areas and the preparation of the preliminary scheme relating thereto, a graphical method based on the hypothesis that, in the sections, the line of the ground is formed by two straight lines which meet on the centre line peg.

He deals with all the areas or part areas of the ordinary sections found in practice and gives them values by means of formulæ containing the algebraic sum of the half product of the segments $a = A_v A_m$ = width of the bed, $b = B_v B_m$ = width of the section, $k = OK$ = constant distance, in each cross section, between the bed and the point O at which the slope meets the vertical through the peg, and then $q = OP = k + h$, wherein h is the red ordinate of the section. For dissymmetrical sections (section 3), for mixed sections (sections 4 and 5) and for uniform sections as opposed to mixed sections (section 3), these segments ought to be either sub-divided or clearly separated in their corresponding leading and trailing parts (a, a_m, q_v, etc.) and, in addition, for mixed sections account should be taken of the segment $c = KC$ and for the uniform sections following or preceding them the segment n = average height of the trapezium PKN_1N_2 opposed to the triangle PKC of the mixed.

The numerical operations indicated by the formulæ are done graphically at the same time as the diagram of the areas is constructed.

a) For all the sections :

1. The verticals corresponding to the cross sections are drawn down and a horizontal datum line o on which to the right of each section and at a distance $2l$ (l = base to which reduced) a pole L is marked ;

2. The diagram of the q's is drawn, that is to say, the longitudinal profile in relation to as many horizontals k as there are groups of cross sections, each horizontal being traced below or above o, as it is a case of fill or cut, and at a distance equal to the corresponding section k characteristic of the group. For the dissymmetrical sections and the mixed, as we have two values of k, i. e. $k_v = O_vK$ ahead and $k_m = OK$ behind, the profile should be drawn out twice ;

3. The horizontals α are drawn at a dis-

tance from o equal to the segment $o\alpha$, the measurement of the area $\alpha = A_v A_n = \frac{ak}{2}$ constant for each profile taking for abscissæ on o, $OA = \alpha$ to the left of the vertical for a given section of the profile and in carrying through A the parallel to the radius LK; this parallel meets the vertical of the profile at the point α through which the horizontal α passes. For the horizontals α too there is only one (α_r for the fills and α_s for the cuts) in the symmetrical sections; there are two (α_v and α_m) for the dissymmetrical sections (both on the same side) and for the mixed (for the two opposite sides).

Fig. 1.

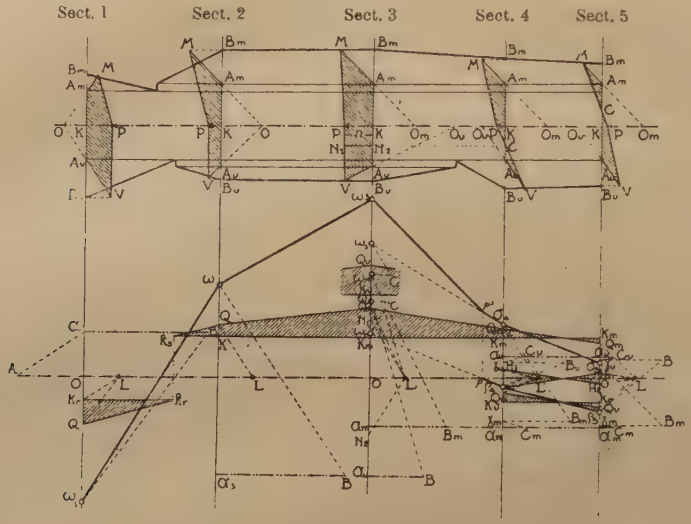

Fig. 2.

Figs. 1 and 2.

b) ***For uniform groups, if symmetrical*** (sect. 1 and 2), we take on the horizontal o, to the right of the section, the abcissa $OB = b$; drawing through B, the parallel to the radius LQ corresponding, we get in the vertical of the section, the point ω, which by $o\omega$ gives the measurement of the section, on the base l; if they are *dissymmetrical* (sect. 3), the method is the same, but the parts ω_v and ω_m of the section in front of and behind the vertical through the peg, are calculated separately, the total being made equal to $\omega = \omega_v + \omega_m$.

As the figures shew, the same method is followed for the mixed groups (sect. 4 and 5) and for the parts ω_v and ω_s of the uniform sections preceding or following a mixed section (sect. 3).

In all cases, the ordinates are got in the position needed for the construction of the diagram area (drawn in figure 2) : we deduce therefrom, as one knows, the line of the volumes and, consequently, the distribution and calculation of the volumes to be handled and the distances to be carried; the whole graphically on a single sheet of paper, on which it is also well to make a record of the quantities and the expenditure on the earth work.

[621 .133.3 (.71) & 669 .1 (.71)]

Nickel steel for locomotive boilers, (1)

By CHARLES McKNIGHT,
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Figs. 1 to 7, pp. 855 to 856.

(*The Railway Mechanical Engineer.*)

Two years ago the Canadian Pacific Railway in designing some new locomotives desired to increase the capacity and efficiency of their motive power without materially increasing the total weight. This could be done by increasing the boiler pressure 25 % but to do that without increasing the thickness of the boiler plate appeared on the face of it to be an impossibility. But the Canadian Pacific successfully accomplished the apparently impossible by taking a step that they had been investigating and considering for some time. This was the use of 3 % nickel steel boiler plate of 70 000 lb. per square inch minimum tensile strength. Approximately 30 % stronger than carbon steel, its use permitted an increase in boiler pressure from 200 to 250 lb. per square inch without any change in thickness of the boiler plate. A total of 44 locomotives were thus constructed for this company in 1926; 24 *Pacific* and 20 *Mikado* type. They have fully justified the expectations of improved performance and efficiency.

Such an unprecedented step on as large a scale as this immediately aroused countrywide interest, not only among railroad officials but among builders and users of other types of boilers. Several railroads have translated this interest into actuality in the shape of one or more locomotives; for example, the new high-pressure locomotives of the Delaware & Hudson Railroad have nickel steel boilers. Others are still seriously considering it and experimenting. The same is true of manufacturers of large stationary boilers.

Unquestionably the Canadian Pacific Railway independently pioneered in this development. It detracts in no way from this road to say that inquiry has since developed, that this action was anticipated more than a quarter of a century ago when the Baldwin Locomotive Works built a locomotive with boiler shell, firebox and other important parts of nickel steel. A few years earlier nickel steel plate had been employed for the tubes and boilers of the U. S. cruiser *Chicago*. The first stationary boiler of nickel steel was also built about the same time. That these were not followed by more was probably because the demands were not as great then as now and also a better plate was not necessary.

Ascertaining definitely that these boilers had been built so long ago settled quite as definitely the question of what life could be expected of nickel steel. The boilers of the *Chicago* are still in service after 30 years use, although the

(1) Paper presented before the semi-annual meeting of the American Society for Steel Treating at Montreal, Quebec, 16-17 February 1928.

TABLE I.

Average of 523 tests on 3 % nickel steel boiler plate.

	Per cent.				
	Average.	Specified.		Average.	Specified.
Carbon	0.163	0.20 maximum.	Ultimate tensile strength, lb. per square inch.	77 880	70 000 minimum.
Manganese . .	0.557	0.40-0.80	Yield point, lb. per square inch.	47 550	50 % ultimate tensile strength.
Phosphorus. .	0.021	0.045 maximum.	Elongation in 8 inches, per cent	26.33	1 600 000, minimum 20.
Sulphur. . . .	0.029	0.045 maximum.		U. t. s.	
Silicon	0.203	Not specified.	Reduction of area, per cent.	54.15	50
Nickel	2.960	2.75-3.25	Impact value, Izod, foot-pounds.	63.4	

demands are now light. The same is true of the locomotive, which still operates after more than 25 years of service.

Comparison of nickel and carbon steel plates.

During the past two years, beginning with the plates rolled for the Canadian Pacific Railway, data have been collected showing the physical characteristics of the low carbon 3 % nickel steel boiler plates. The averages of results of tests on all but a few nickel steel plates which have been utilized during this period for boiler construction are shown in table I and compared with a number of tests on carbon steel boiler plate in table II.

Primarily nickel steel is used because of its higher strength with practically the same ductility as carbon steel. But, in addition, the other qualities which are desirable, even necessary, in a boiler are developed with nickel steel to a higher degree than with any other material, so that it is peculiarly, almost uniquely, suited to boiler requirements. These additional qualities are its physical characteristics at high temperatures, its excellent impact values, its resistance to embrittlement in boiler service and its uniformity.

High temperature characteristics of nickel steel.

Physical testing of boiler materials at room temperatures and under usual conditions can at best be only an approximate guide to the suitability of the material for boiler service. At best the working temperature of a boiler is some 200° F. higher, in a temperature range where changes occur in the nature of the steel. But even worse, with the temperatures and pressures now being used, the steel enters the « blue-brittle » range, where an ordinarily soft and ductile metal unaccountably loses its toughness and becomes very brittle, although the

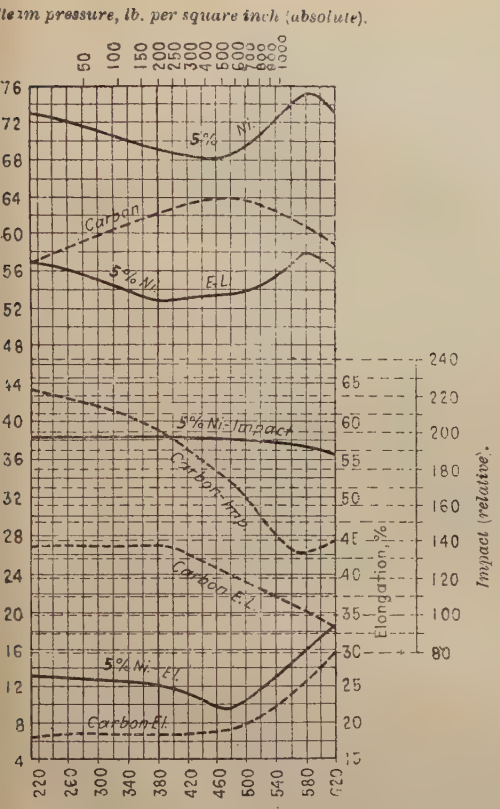
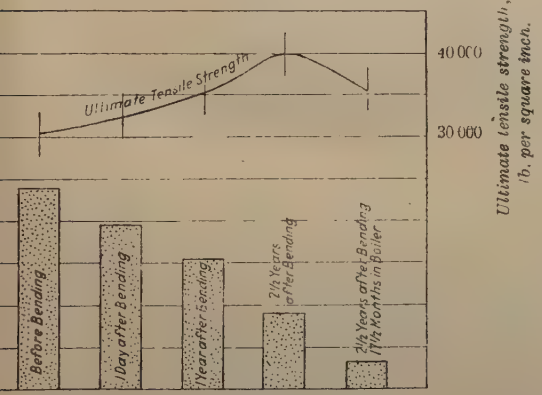


Fig. 1. — Characteristics of 5 % nickel and straight carbon boiler sheets at elevated temperatures.


Ultimate Tensile Strength
Before Bending
1 Day after Bending
1 Year after Bending
2½ Years after Bending
2½ Years after Bending 7½ Months in Boiler
Ultimate tensile strength, lb. per square inch.

Service test of carbon steel boiler plate (C 0.11 — M 0.53 — P 0.026 — S 0.31), 0.8 inch thick × 22.5 feet long, annealed before bending at 1 685° F.

— Graphic of data obtained on full size long time tests of boiler plate.

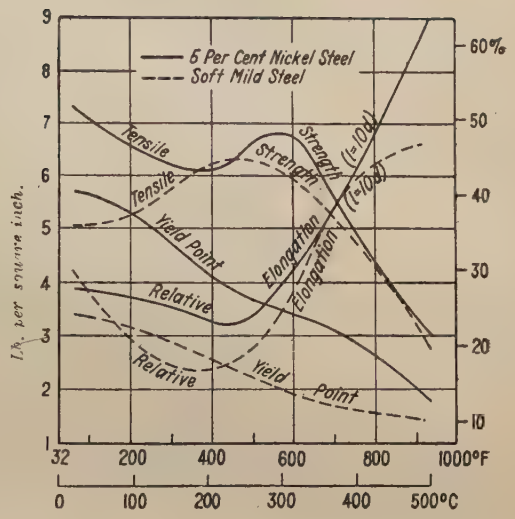


Fig. 2. — Tensile characteristics of 5 % nickel and straight carbon boiler steels at elevated temperatures.

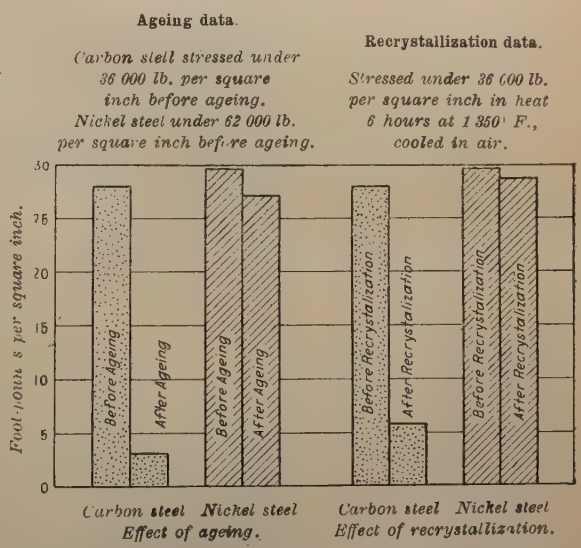

Ageing data.
Carbon steel stressed under 36 000 lb. per square inch before ageing. Nickel steel under 62 000 lb. per square inch before ageing.
Recrystallization data.
Stressed under 36 600 lb. per square inch in heat 6 hours at 1 350° F., cooled in air.
Foot-pounds per square inch.
Before Ageing
After Ageing
Before Ageing
After Ageing
Before Recrystallization
After Recrystallization
Before Recrystallization
After Recrystallization
Carbon steel
Nickel steel
Effect of ageing.
Carbon steel
Nickel steel
Effect of recrystallization.

Fig. 4. — Comparative ageing and recrystallization tests on 5 % nickel steel and special boiler steel (0.11 % carbon).

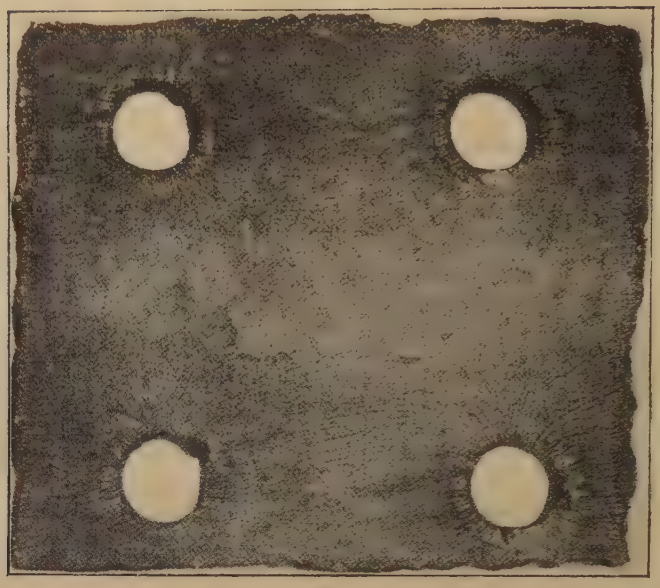


Fig. 5. — Carbon steel firebox plate showing corrosion along stress lines.

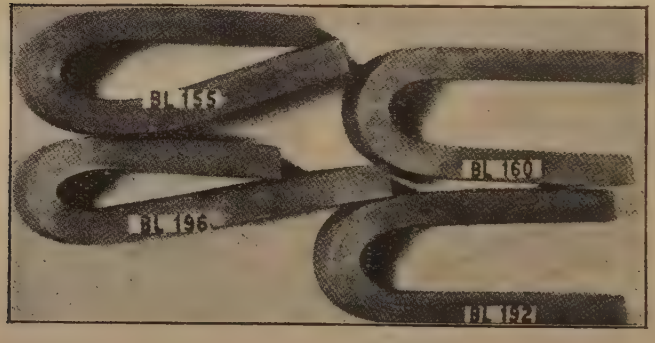


Fig. 6. — Bend test on high tensile (100 000 lb) nickel steel plate.

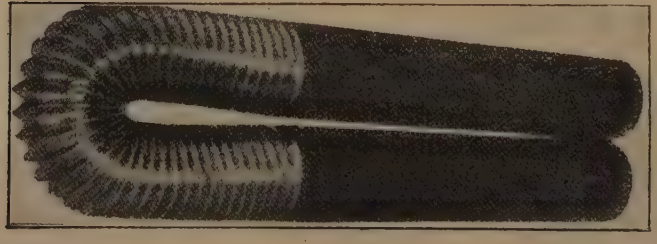


Fig. 7. — Nickel steel staybolt threaded bend test.

strength is greater than when cold. A piece of boiler steel which can be bent double when cold will break off short at this temperature and the fracture will have the characteristic blue color which alike indicates the temperature and the derivation of the term « blue-brittleness » (1).

TABLE II.

Average of 385 tests on carbon steel boiler plate.

	Average per cent.		Average.
Carbon	0.193	Ultimate tensile strength, lb. per square inch.	59 200
Manganese	0.401	Yield point, lb. per square inch	36 200
Phosphorus	0.022	Elongation in 8 inches, per cent	28.64
Sulphur	0.033	Reduction of area	(Not determined).
		Impact, Izod	(Not determined).

A great deal of research into this matter of high temperature characteristics of steel has been done recently. The data most applicable here seem to be those incorporated in figures 1 and 2 (2) (3). The superiority at any temperature of the nickel steel over carbon steel is apparent. In figure 1 at 480° F. corresponding to a saturated steam pressure of about 500 lb. per square inch gage) the properties of nickel steel are relatively low. Nevertheless there is a superiority over the special carbon boiler steel of 12.3 % in yield point, 7 % in tensile strength, 28 % in elongation and 8.5 % in impact resistance. The data embodied in this curve are taken directly from the authority quoted and the figures for carbon steel refer to a « special boiler steel » of German manufacture.

Embrittlement in service.

The high temperature characteristics of the metal are buttressed by another and unique feature. The boiler designer has always been faced by the specter of embrittlement in service. It has long been known that ordinary tensile tests are of little value as indices of performance in a boiler. Impact tests, resorted to as a means of detecting brittleness prior to service, have failed in their purpose. How misleading such tests can be is shown by the report of Goerens previously referred to. He discusses the phenomena of « ageing » and « recrystallization » of boiler plate in service and then gives interesting data on some full-size long-time tests. The data are too

(1) See « Tensile Properties of Boiler Plate at Elevated Temperatures », H. J. FRENCH. (*Transactions*, American Institute of Mining and Metallurgical Engineers, 1922, and discussion thereof.)

(2) Data from « Die Kesselbaustoffe », by P. GOERENS (*Zeitschrift des Vereines Deutscher Ingenieure*, 19 January 1924, vol. 68, No. 3).

(3) The physical data presented in this paper should be considered comparable only in each given set of figures. This is particularly true of elongations and impact values, which vary widely according to the test specimen used.

In examining the results of several thousand tensile determinations, the author encountered discouraging discrepancies, due principally to varying conditions of test. The main factor causing discrepancies seemed to be the finishing temperature of the steel as rolled, which caused surprising variations of results. If this factor is disregarded, it is possible to obtain excellent tensile characteristics from a plate entirely unsuited for fabrication or subsequent service in a boiler.

In the work on nickel steel in our own and associated laboratories, the tensile test specimen was invariably the American Society for Testing Materials standard 8-inch plate specimen and the metal had been given the thermal treatment customary for this type of boiler steel ; *i.e.*, a retarded cooling after rolling.

comprehensive and detailed to be included here, but in figure 3 are shown graphically the essential results. Briefly, he first annealed a carbon steel boiler plate (0.8 inch by 5.25 feet by 22.5 feet) and then formed it by bending as it would be formed in a boiler. Tested before bending and at intervals of one day, one year, 2 1/2 years without actual service, and 2 1/2 years with 17 1/2 months in actual boiler service, it was found that the strength and elastic limit increased a little progressively while the elongation decreased after bending and then remained practically constant. But most striking is the serious dropping off in impact resistance, from 24.0 to 3.3, a decrease of 86.25 %. Small wonder that frequent inexplicable boiler failures occur through embrittlement and cracking.

In a way similar to ageing, recrystallization affects boiler plate but not to so marked a degree. Fortunately, also, the effect of recrystallization is not markedly apparent until temperatures in excess of 900° F. are encountered. Practically, in a boiler the effects of either ageing or recrystallization or both may occur because the plates are stressed during forming and bending in the manufacture of the boiler or they may occur after the boiler is in commission as a result of stresses which are induced by differences in the temperature at various parts of the boiler. The injurious effects will become more noticeable as the boiler pressure and consequent thickness of the plates increase because of the greater difficulties of forming, bending and riveting heavier plate as well as because of the fact that increased heating surface and higher rates of evaporation offer more favorable conditions from temperature differences and additional stresses in the boiler.

Nickel steel resists these two destructive agencies to a marked degree, probably better than any other steel. The results of comparative ageing and recrystallization tests on 5 % nickel steel and « special boiler steel » (carbon 0.11 %; manganese, 0.53 %; phosphorus 0.026 %; sulphur 0.031 %) are embodied in figure 4 which shows conclusively the vast superiority of the nickel steel.

Uniformity of nickel steel.

It is well known that there is marked variation both in the chemical composition and tensile results of test pieces taken at various parts of a carbon steel boiler plate (1) and that when specifications are met with tests from one place the plate may diverge dangerously from the requirements at other places. Experience has shown and it has often been commented on that one can confidently expect a much smaller variation with nickel steel. The tables III and IV show the satisfactory results of several top and bottom tests, as well as the uniformity of analysis.

The valuable bend test has been satisfactorily met. The specifications usually call for a top transverse bend test and, as a general rule, nickel steel not only meets the full requirements of a 180° bend about a pin whose diameter equals the plate thickness, but can be closed down flat on itself without cracking. There is little difference between the bends on carbon steel and nickel steel. As a matter of fact, one user stated that the bend tests on nickel steel were the best he had ever seen.

Manufacture.

In the industrial application of nickel steels, consideration had to be given to the proportion of nickel to be used in the steel. It was eventually decided to use a 2.75 % to 3.25 % nickel steel. The desirable characteristics of nickel steels are obtained with this steel, although to

(1) See « Experiments on the Segregation of Steel Ingots in Its Relations to Plate Specifications », by C. L. Huston. (*Proceedings*, American Society for Testing Materials, vol. VI).

TABLE III.

Uniformity of tests of nickel steel.

TEST.	Yield point, lb. per square inch.	Tensile strength, lb. per square inch.	Elongation, per cent.	Area, per cent.
Bottom long	40 600	77 800	25	56.1
Top trans.	43 600	76 700	20	36.0
Bottom long	41 100	77 900	28	57.0
Top trans.	42 200	77 700	25	48.9
Bottom long	43 500	78 400	25	58.2
Top trans.	43 100	78 600	25	49.1
Bottom long	42 100	77 400	26	59.7
Top trans.	41 900	78 000	22.5	51.4
Average variation, per cent	2.86	2.70	2.37	11.4
Average variation, per cent, carbon steel, picked at random, same number	...	6.02	...	...

Analysis :	Carbon.	Manganese.	Phosphorus.	Sulphur.	Nickel.
Per cent	0.19	0.55	0.012	0.035	2.95

TABLE IV.

Uniformity of analysis of nickel steel.

	Top, per cent.		Bottom, per cent.	
Carbon	0.29	0.22	0.21	0.15
Manganese.	0.72	0.69	0.73	0.76
Phosphorus	0.018	0.018	0.016	0.016
Sulphur	0.021	0.024	0.027	0.023
Silicon.	0.25	0.25	0.23	0.22
Nickel.	2.62	2.68	2.66	2.66

a slightly less degree than with five per cent nickel. The cost is less and there is the added advantage that such a steel is a standard of which many thousands of tons of plate have been made, the total eclipsing the aggregate amount of all other alloy steel plate ever rolled. Table V gives in abbreviated form the physical characteristics which have been obtained in tests of this steel and which are concordant with the results with 5 % nickel steel.

TABLE V.

Properties of three per cent nickel steel.

	Tensile tests.			Ageing tests.		
	68° F.	486° F.	660° F.	Sample.	After ageing	After recrystallization.
Ultimate tensile strength, lb. per square inch	62 200	64 000	54 100	62 300	66 900	60 000
Elastic limit, lb. per square inch	42 700	28 500	25 600	42 700	59 700	38 000
Elongation, per cent.	27.5	21.9	33.1	36.0	36.0	33.0
Reduction of area, per cent.	71.0	63.0	73.1	71.0	67.0	70.0
Impact, foot-pounds	30.6	29.8	28.4	30.1	27.7	29.0

The decision having been made to employ a 3 % nickel steel, there remained only to fit the steel to the boiler design. At that time a steel of 70 000 lb. per square inch minimum ultimate tensile strength was not only adequate, but generously so. A steel having between 0.15 % and 0.20 % carbon was, therefore,

decided upon and it has not been necessary thus far to depart from that standard.

When the first plates were being rolled, it was mutually agreed by the consumer and the manufacturer that in order to take the most advantage of the contained alloy, the nickel steel should be « killed » (1), although most boiler plate is not so treated.

With a killed steel, the yield is less than with the ordinary steel, on account of the piped portion of the ingot which must be discarded. A fair figure is 60 % or more usable product from the ingot. Also a killed steel is prone to have surface defects, such as « snakes » and « pits ».

These variations in practice with killed steels do not detract from their desirability but are, as a matter of fact, guarantees of superior quality. Killed steels for boiler plate have gained a great deal of favor recently and by some it is thought that for high pressure work they will eventually supplant entirely the present type. They have one great advantage in that their defects are usually on the surface and apparent on inspection.

Nickel steel for plate is always killed in modern practice and therefore presents the same problems of yield and surface to the manufacturer. It is essential that the steel be well made, that approved ingot molds and hot-tops be used, that the heating of ingots prior to rolling be given careful attention and that the rolling itself be conducted so as to ensure the best possible surface. With these precautions, experience has shown that there is little difference between nickel steel plate and other killed steels, either in yield or in rejections on account of surface defects.

One of the problems which was encountered and which had to be overcome by the manufacturer was that of unintentional heat treating of the nickel steel. Ordinary boiler plate is finished at the mill in a wide range of temperatures, depending largely on the thickness of the plate, and is straightened immediately after rolling. The continued passing of the plate back and forth between the leveling rolls has almost the same effect as a quench. This does not mean a great deal of difference on the low carbon steels but when nickel steel was so treated, the quick cooling hardened the plates considerably. It was found necessary to roll the plates at a temperature sufficient to ensure their finishing at a good red heat, after which the plates were rolled off the hotbed and piled one on top of the other and later covered with sand. Using this method, it took the plates about eight hours to cool down to a black heat and this anneal, if it can so be termed, resulted in a better product and improved bend tests.

No difficulties in fabricating nickel steel plate have developed and no variation from standard practice has been necessary. Either carbon steel or nickel steel rivets can be used, as dictated by design, and welding with the arc or gas process is perfectly feasible. Nickel steel welding rod should be used.

Possibility of higher strengths with nickel steels.

The plates in the boilers of the *Chicago*, of 3.5 % nickel steel, had an ultimate tensile strength of 80 000 to 90 000 lb. per square inch, a yield of 50 000 to 63 000 lb. per square inch with an elon-

(1) Briefly, a « killed » steel differs from an « open » or « rimming-in » steel in that sufficient silicon, manganese, aluminum or other element is added to render the steel substantially gas-free after solidification. A secondary effect is that, blowholes being no longer present in sufficient volume to counteract it, the steel exhibits piping along the center-line of the ingot. To lessen this, it is essential to use hot-tops and properly designed molds. Silicon is rarely in excess of 0.30 % in such steels.

gation in 8 inches of over 20 % and they also met with full bend test (1).

The analysis of nickel steel now being extensively used for boilers was selected not because it was the ultimum obtainable, but because it meets the present requirements of strength adequately with excellent subsidiary characteristics. It now seems possible that the extension of some work already undertaken may make available another nickel steel as much superior to the present nickel steel as it is superior to carbon steel.

Corrosion and firebox cracks

While only a small consideration in the adoption of nickel steel for boilers, a feature not to be overlooked is that of the increased resistance to corrosion. It is, of course, well known that above 20 % nickel confers practical immunity from the types of corrosion met with in boilers and this immunity is proportional to the nickel content below that figure. With 3 % nickel, tests show a higher resistance to corrosion than the usual boiler materials.

There always has been trouble with firebox sheets of locomotive boilers cracking between the staybolt holes and this trouble is apparently increasing with the increase in the size of boilers and the pressures employed. It is usually considered that this cracking is fundamentally due to corrosion, but we feel that corrosion is of secondary importance. It is recognized that when a steel has been overstressed and then subjected to corrosive agents, the corrosion will take place more rapidly where the stress has occurred (2). That this condition exists in firebox sheets which crack, seems to be demonstrated by the fact that even a superficial examination will show that the cracks running from one staybolt hole to another take on the appearance of magnetic lines of force (see fig. 5); *i. e.* they follow the stress lines. We believe it unusual, if it occurs at all, for these cracks to run longitudinally or parallel with the direction of least strain in a firebox sheet. If these conclusions are justified, then it is not so much a question of corrosion as one of strength and resistance to embrittlement and the obvious remedy is to apply a stronger sheet.

Nickel steel is of double advantage here as its higher strength and resistance to embrittlement enable it to resist the primary cause, while it is also naturally more resistant to corrosion. The first to make practical use of nickel steel for firebox sheets was the Canadian National Railroad about three years ago and since then a number of others have made experimental installations. There has been no failure of nickel steel plate from this cause and, on the other hand, in the cases where it has been applied as a cure, it is reported as being effective.

Boiler tubes and staybolts

For boiler tubes the situation regarding corrosion is exactly the reverse of that for shell plate, as corrosion-resistance is here the primary consideration and the increased strength has little to do with it. Boiler tubes running from 0.10 to 0.20 % carbon and containing about 2.0 % nickel have shown in actual service a life of from seven to fifteen times that of carbon steel tubes in districts where the water is bad. This, of course, has been sufficiently encouraging to warrant the extended use of nickel steel boiler tubes in bad water districts and in addition there are a large number of railroads who either have nickel steel boiler tubes under test or are using them

(1) Private Communication, U. S. Navy. Also « Nickeled Steel », by A. L. Colby (*Proceedings*, American Society for Testing Materials, vol. III, 1903).

(2) See « Rissbildungen und Anfressungen an Dampfkesselelementen », by Körber and Pomp (*Korrosion und Metallschutz*, May, 1927).

as a regular material on some portions of their line. Their use is not entirely new, as tubes with a higher percentage of nickel were used by several of the navies, among them our own, as long ago as 1900, and ones with a lower percentage only a few years later. The unexplained peculiarity of these tubes has been the fact that boiler scale collects to a much less degree on them than on the ordinary tubes (1). It has been report-

TABLE VI.

Corrosion tests.

a) *Exposure corrosion tests.*

	Loss in weight, lb. per square foot per year.	
	Sea water.	Fresh water.
Wrought iron.	0.1409	0.1275
Soft steel	0.1612	0.1204
3 °/₀ nickel steel . . .	0.1173	0.1021

b) *Twelve months' exposure : Sea water.*

	Loss in weight, per cent.
Wrought iron	1.89
0.25 °/₀ carbon steel	1.72
3 °/₀ nickel steel	1.36

c) *Exposure to steam and salt water.*

	Loss in weight, per cent.	
	Steam 2 months.	Boiling 3 months. 10 °/₀ NaCl solution.
Bessemer steel . . .	0.58	1.81
Open-hearth steel . .	0.33	1.98
3 °/₀ nickel steel. . .	0.27	1.00

Results taken from « Nickel Steel : Synopsis of Experiment and Opinion », by D. B. BROWNE, (*Transactions*. American Institute of Mining and Metallurgical Engineers).

(1) « Non-Corrosive Nickel Steel Boiler Tubes », by A. L. COLBY (*Proceedings*. Society of Naval Architects and Marine Engineers, vol. 11, p. 135). Discussion elicited the fact that in a comparative test of two boilers, one tubed with ordinary tubes and the other with 3 °/₀ nickel steel tubes, after five months' service the nickel steel tubes were smooth, glossy and free from attached scale, while the ordinary tubes were rough and pitted, with scale covering the pitted surface. An eighteen months' trial showed a 7 °/₀ fuel economy in favor of the boiler with nickel steel tubes.

TABLE VII.

Comparison of staybolt materials.

MATERIAL.	Carbon.	Manganese.	Silicon.	Nickel.	Treatment.	Yield point, lb. per square inch.	Tensile strength, lb. per square inch.	Elongation.	Reduction of area	Brinell hardness No.	Impact.	Endurance limit.	Stress to cause failure at 15 000 cycles.
Wrought iron. . . .	0.02	0.04	0.13	...	As received	33 000	49 400	34.0	46.4	103	45	...	...
					1 650° F. C.	30 800	46 500	36.5	49.3	95	32	...	43 000
Wrought iron. . . .	0.06	0.04	0.09	...	As received	34 000	48 600	34.8	51.2	102	46	31 000	48 000
					1 650° F. C.	29 400	45 500	37.3	54.4	92	38	28 000	46 000
Staybolt steel . . .	0.06	0.02	0.01	...	As received	29 900	46 300	41.3	73.3	86	62	28 000	45 000
					1 650° F. C.	19 300	49 700	41.0	69.3	88	17	27 000	44 000
Staybolt steel . . .	0.15	0.36	0.03	...	As received	32 250	58 800	39.5	65.2	110	69	30 000	49 000
					1 650° F. C.	33 000	53 000	38.3	62.1	101	12	30 000	46 000
Staybolt steel . . .	0.18	0.47	0.07	...	As received	43 500	70 100	32.0	53.7	123	27	...	...
					1 650° F. C.	34 100	63 800	32.0	51.1	112	9	31 000	49 000
Nickel staybolt steel.	0.10	0.07	0.02	2.07	As received	39 600	53 000	41.8	72.7	104	87	...	...
					1 650° F. C.	41 500	53 700	43.5	79.0	102	87	...	53 000
Nickel staybolt steel.	0.08	0.04	0.02	1.98	As received	40 700	54 900	40.0	76.9	107	82	35 000	...
					1 650° F. C.	42 700	55 100	43.8	77.0	103	83	32 000	51 000

ed in at least one case where a boiler was tubed partly with carbon steel and partly with nickel steel, the nickel steel tubes outlived three sets of carbon steel and when they were removed they were found to be in practically the same condition as when they came from the mill, that is, with the mill scale perfectly apparent.

The primary load on a staybolt is that which it is designed to carry — a pure tensile stress which is not excessive in relation to the strength of the materials used and which is numerically equal to the load due to steam pressure on a square of area equal to the product of the staybolt spacing distances. But a far more important load is that occasioned by expansion of the firebox and weaving of the boiler. In firing a cold boiler the firebox begins to expand longitudinally before the shell plates are hot, which results in a bending of the staybolts. Eventually, the shell is also heated and expands, so that the bending is to some degree recovered, but this recovery is never entirely complete, since there is always a marked temperature difference between the firebox sheet and the outside shell.

Furthermore, the inside of a boiler where it is in contact with hot gases is very sensitive to temperature changes. For example, the opening of the firebox door will almost instantly cause a contraction of the arch tubes, and to a lesser extent, the boiler tubes. With the closing of the door, expansion re-occurs. This movement is quite marked and has been measured. Any change in position of the inside firebox is relative to the outer shell of the boiler and naturally, therefore, causes bending of the staybolts. In addition, the entire locomotive has a certain amount of vibration.

The result of all these factors is that staybolts are subject to vibration and continual, even if slight, bending motion while under tensile stress, and ideal fatigue conditions are established, which may lead to a failure.

Corrosion is also one of the important factors affecting staybolts. Located in the worst places in a boiler from a viewpoint of corrosion and subjected to stresses and to a temperature difference between the ends, both of which induce chemical corrosion, the staybolt has always been peculiarly subject to rusting and pitting and one of the main considerations influencing the choice of material has been the ability to resist corrosion.

Steel has been replacing other materials used for staybolts quite rapidly and of the various compositions of steel used it is noteworthy that almost all contain nickel in amounts varying from 0.50 to 3.50 %. The analysis most often used is a very low carbon 2 % nickel steel. For staybolt service such a steel is superior to any other material as it is strong enough for the duty, yet remarkably ductile, has good resistance to fatigue and remarkable impact values. On test this type of steel has consistently shown impact values of such high order that no other steel is in the same class.

A comparison between staybolt material of wrought iron, steel and nickel steel is shown in table VII.

[625 .251]

Calculating the stopping distances of trains,

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(*The Railway Mechanical Engineer*).

Few air brake supervisors and foremen are high school graduates and fewer still ever went to college. In the majority of cases they have arrived at their present positions through many years of very practical training either as a locomotive engineman, or in the brake repair room in the shop. Usually, they have started railroading in their early youth. So far, I have been unable to find a handbook of which the author has appeared to be cognizant of this situation. Quite often they skip seemingly unimportant steps in the derivation of formulas with a nonchalance that is surprising. Undoubtedly, it may seem simple to the author, but it is all Greek to many men who are expected to use the information.

This presents a situation, however, that is serious in many respects. It is a customary thing for the air brake supervisor to be called into court as a witness to give expert testimony. Testifying for the railroad in rear end collisions or highway crossing accident cases means that he must know his stuff. The average lawyer is never satisfied with the mere statement of a formula; he usually asks questions relative to the derivation, if for no other object than to embarrass or confuse the witness.

Take for example the formula commonly used in computing the stopping distance of moving trains. This formula, which is

$$\frac{V_1^2}{30\,Pef} + V_2T$$

is found in practically all handbooks on air brakes. Still, the writer will challenge anyone to find in any of the handbooks an explanation of the constant 30. It is indeed a delight to study the derivation of such a formula as this and note how the author blithely tells us to use this constant, but neglects to tell what it is and where it came from.

In making studies of stopping distances of moving bodies, an understanding of certain fundamentals is necessary if the subject is to be of any material value to the reader. It is not our purpose in this discussion to dwell upon the mechanics of the subject in detail, but to show the derivation of some of the terms or values used in this formula, which is so important to air brake men.

Explanation of the train-stop formula

In the formula given in the preceding paragraph

V_1 = Velocity in miles per hour (before the brake application starts),

V_2 = Velocity in feet per second when the brake application starts,

30 = A constant,

P = Braking ratio,
e = The efficiency of the brake rigging,
f = Coefficient of friction,
T = Time required to get the brakes applied, in seconds.

The miles per hour, V_i is found by multiplying the number of feet per second by the number of seconds per minute and the number of minutes in one hour (which gives the number of feet per hour) and dividing by 5 280, the number of feet per mile, which gives the speed in miles per hour. The speed in feet per second, for example, at one mile per hour, is found by dividing 3 600, the number of seconds per hour, into 5 280, the number of feet per mile; thus

$$\frac{5\,280}{3\,600} = 1.467.$$

If the speed in miles per hour is known, the speed in feet per second may be found by multiplying 1.467 by the speed in miles per hour; thus $1.467 \times 60 = 88$, or 88 feet per second, at 60 miles per hour. If the time consumed in seconds in running 1 mile is known, the speed in miles per hour can be determined by dividing the time consumed in running one mile (in seconds) into the number of seconds in one hour, thus

$$\frac{3\,600}{60} = 60 \text{ miles per hour, or}$$

$$\frac{3\,600}{120} = 30 \text{ miles per hour.}$$

The value of the braking ratio P refers to the relation of the total braking force (brake shoe pressure) to the light weight of a car. For example, consider a car weighing 100 000 lb., with a total braking force of 90 000 lb., the braking ratio is

$$\frac{90\,000}{100\,000} \text{ or } 90\ \%.$$

The recommended braking ratio for freights cars is 60 % of the light weight and for passenger cars it is 90 % of the light weight. These ratios are based on 50 and 60 lb. brake cylinder pressure, respectively.

Now consider the car above referred to as having a braking ratio of 90 % of the light weight and assume that there is a load of 20 000 lb. in it, making the total weight, 100 000 + 20 000 = 120 000 lb. The braking ratio is now

$$\frac{90\,000}{120\,000} \text{ or } 75\ \%.$$

Another important factor in this connection is the actual brake cylinder value. Assuming the 100 000-lb. car in question, braking at 90 %, based on 60 lb. brake cylinder pressure, the braking ratio per pound of brake cylinder pressure is

$$\frac{90}{60} \text{ or } 1.5\ \%.$$

Let us suppose that instead of the car being loaded and obtaining 60-lb. brake cylinder pressure, the car is empty and 90-lb. brake cylinder pressure is obtained, the braking ratio under these conditions would be 1.5×90, or 135 %. On the other hand, if only 50-lb. brake cylinder pressure is obtained, our braking ratio would be 1.5×50, or 75 %. These stand out prominently and appreciably vary the length of stop. Leaking of brake cylinder packing, lack of inspection and inadequate supervision and maintenance are the contributing factors that raise or lower the value P.

The value e refers to the efficiency of the foundation brake rigging or the relation between the actual and calculated brake shoe pressure; the former may be more or less than the latter. However, whether it is more or less will depend upon design and maintenance. It will be obvious that adequate supervision and proper maintenance play an important part in assuring that the value e does not

vary materially. Considering again the car above referred to as weighing 100 000 lb. and braking at 90 %, if the brake rigging efficiency is 80 %, then the braking ratio would be 0.80 × 0.90, or 72 %.

The value *f* refers to the coefficient of friction and may be defined as the measure of tangential force acting on a wheel in relation to the normal brake shoe pressure. This value varies with the speed, time and other conditions which tend to create what may be defined as lubricant between the brake shoe and the wheel with which it is in contact. Figures taken from the report of the Westinghouse-Galton tests indicate for example at 40 miles per hour, that the maximum and minimum coefficients of friction were 0.194 and 0.088, respectively and the average or mean was 0.14.

The product of *ef* is termed the efficiency factor and if raised or lowered singly or otherwise, the stopping distance will be varied correspondingly.

The constant 30, which none of the handbook writers seem to want to talk about, refers to necessary factors in the mechanics of the subject and is found by dividing the square of 1.467 into 2×32.2. This equals 29.92 and for convenience is taken as 30.

$KE = 1/2\ MV^2$ where,
KE = Kinetic energy in foot-pounds.
M = Mass,
V = Velocity in feet per second.

The mass M is equal to the weight, divided by the acceleration due to the action of gravity or

$M = \frac{W}{g}$, in which
W = weight or force,
g = 32.2 feet per second per second, the acceleration due to gravity.

Substituting this value of mass in the kinetic energy formula, we have

$$KE = \frac{WV^2}{2g}.$$

It will be remembered that the value of V_1, the velocity, expressed in miles per hour, is equal to 1.467 times V, the value of the velocity expressed in terms of feet per second. If we substitute this for V in the equation, it becomes

$$KE = \frac{W(1.467V_1)^2}{2 \times 32.2}.$$

It has already been pointed out that $2 \times 32.2 : 1.467^2 = 30$. Hence

$$KE = \frac{WV_1^2}{30}.$$

It is for the same reason that the constant 30 is used in that part of the formula for the stopping distance in which velocity is expressed in miles per hour.

The braking force is that which prevents or stops the motion of a car. When a car is in motion it possesses kinetic energy, or a certain capacity for doing work. It is expressed in foot-pounds and is equal to one-half of the product of the mass times the square of the velocity, as explained above. As an example, the number of foot-pounds of work contained in a car moving 30 miles per hour (44 feet per second), weighing 20 000 lb. would be $20\,000 \times 30 \times 30 : 30 = 600\,000$ foot-pounds.

When brake shoe pressure is applied to the wheels of a moving car the kinetic energy in the car works against the resistance of friction and must be overcome if the speed of a car or train of cars is to be retarded.

Tests which have been made indicate that when a full service brake application of 24 lb. brake pipe reduction is made pneumatically in approximately 15.5 seconds from an initial brake pipe pressure of 110 lb. with a nine-car passenger train, then the value T plays an important part in train stop computations. In other words this factor refers to the time required to obtain a full service brake application. The time to get

the brakes applied, times the velocity in feet per second, V_2, should be added to the value obtained from

$$\frac{V^2}{30\,Pef},$$

although there may be some deceleration realized during the time the brakes are being applied. Making this addition will allow a margin for safety.

A practical application.

We are now ready to apply the formula in the stoppage of a nine-car train from an initial speed of 40 miles per hour

$$\frac{V_1^2}{30\,Pef} + V_2T$$

or, written another way

$$\frac{40 \times 40}{30 \times 0.90 \times 0.80 \times 0.140} + (58.6 \times 15\ 5) =$$

$$= \frac{1\ 600}{30 \times 0.90 \times 0.80 \times 0.14} + 908 = 1\ 435.$$

If one or more of the factors P, e or f is increased the theoretical stopping distance will be varied

$$\frac{1\ 600}{30 \times 0.90 \times 0.85 \times 0.194} + 908 = 1\ 267.$$

In the last computation 0.85 was used as the value for e and 0.194 for f, the maximum co-efficient of friction recorded in the report of the Westinghouse-Galton tests, instead of 0.80 and 0.14 as in the former case.

From the above it will be noted that the stopping distance from a given speed will vary considerably, depending upon the factors involved in the computation.

In addition to the foregoing, perhaps there is nothing that affects the stopping distance to as great an extent as does the length of the train where pneumatic brakes are employed. It may be of interest to the reader to stress the fact that the longer the train the longer it requires to get the brakes fully applied. A continuous service brake pipe reduction of 20 lb. requires approximately one minute with a train of 75 cars.

As explained above, the braking ratio is materially affected by the load to light ratio of a car or cars. For example, take a train of 75 cars all having light weights of 30 000 lb. each and a load capacity of 60 000 lb. This means that the load to light ratio is

$$\frac{30\ 000 + 60\ 000}{30\ 000}$$

or 3 to 1, and if the braking ratio is 60 % of the light weight the braking ratio of the cars in question is $\frac{20}{60}$, or 1/3 of 60, or 20 %. The stopping distance for such a train is obviously much greater than that for a passenger train where the braking ratio is not materially reduced by the load in the cars.

Stopping a 75-car train

Let us now apply the above formula to the stopping of a 75-car freight train, where

$V_1 = 40$ miles per hour,

$P = 20\ ^{\circ}{}_{o}$,

$e = 80\ ^{\circ}{}_{o}$,

$f = 19.4\ ^{\circ}{}_{o}$,

$$\frac{40^2}{30 \times 0.20 \times 0.80 \times 0.194} + 58\ 6 \times 60 =$$

$$= \frac{1\ 600}{30 \times 0.20 \times 0.80 \times 0.194} + 3\ 516 = 5\ 226.$$

The value P therefore is a factor which must be known before any determination can be reached as to what the stopping distance may be.

In addition to the foregoing it may be necessary to consider the effect of the

gradient. When stops are made on a descending grade the formula is

$$\frac{V_1^2}{30(Pef - G)} + V_2T$$

or if on an ascending grade,

$$\frac{V_1^2}{30(Pef + G)} + V_2T.$$

The value G refers to the per cent grade and is expressed as a decimal. If the gradient involved in a computation is 1/2 of 1 % descending, the decimal 0.005 should be subtracted from the product of *Pef*. If on an ascending grade it should be added to the product of *Pef*.

Example : Find the stopping distance of a passenger train from an initial speed of 40 miles per hour on a descending grade of 1/2 of 1 %.

$$\frac{40^2}{30(Pef - G)} + V_2T =$$

$$= \frac{1\,600}{30(0.90 \times 0.85 \times 0.19 - 0.005)} + V_2T =$$

$$= \frac{1\,600}{4.21} + 911 = 380 + 911 = 1\,291 \text{ feet.}$$

If on an ascending grade we would have

$$\frac{1\,600}{4.51} + 911 = 305 + 911 = 1\,215 \text{ feet.}$$

In the case of a freight train with the following values :

$$\frac{40^2}{30(0.20 \times 0.85 \times 0.19 - 0.005)} + 60 \times 58\ 8 =$$

$$= \frac{1\,600}{0.819} + 3\,528 = 1\,959 + 3\,528 = 5\,487 \text{ feet.}$$

If on an ascending grade we would have

$$\frac{1\,600}{1.119} + 3\,528 = 1\,439 + 3\,528 = 4\,957 \text{ feet.}$$

What a difference in the stopping distance of a freight train of 75 loaded cars on a 1/2 of 1 % grade descending and a passenger train of nine cars on a level track ! But this is not all. The values for P used in the above calculations may be lower than those used; it may be as low as 0.15. This is simply to show that the fast moving freight train with a low braking ratio should be considered when spacing block signals or in the spacing of trains, especially if long, heavy trains are to be operated between passenger trains.

These computations do not take into consideration the delay time encountered in train control territory nor of the effect of the throttle being left open during the progress of the stop. Whatever the delay time may be in seconds it must be multiplied by the speed in feet per second and added to the above calculations.

[656 .257 (.42)]

311-lever power signal frame for London Bridge, Southern Railway.

Figs. 1 to 8, pp. 870 to 875.

(*The Railway Gazette.*)

In *The Railway Gazette* dated 17 February 1928, general particulars were given of the new signal cabin, power frame, and signalling brought into use by the Southern Railway in June 1928 at London Bridge. This power frame, which has 311 levers, is one of the largest placed in service, while it includes many interesting features. It has been constructed in record time, and by courtesy of the Southern Railway and of the Westinghouse Brake & Saxby Signal Co., Ltd., we are now enabled to give a signal plan of the lines and signals it controls and to reproduce a series of photographic views showing the frame erected for test and demonstration purposes at Chippenham prior to transfer to London for wiring up and completion.

Combination of station working.

Prior to grouping the London, Brighton & South Coast and South Eastern & Chatham stations at London Bridge were quite independent, but the association of the two companies necessitated connections from one to the other a short distance beyond the stations, owing to the fact that certain South Easthern & Chatham train services were transferred to « Brighton » metals by virtue of running power arrangements dating from early days. Further, the tracks of the two sections ran side by side for some distance, and in view of the fact that future train service developments may involve still more interworking, it was decided, in introducing the new signalling, to concentrate the control of both stations, together with the Low Level section of the South Eastern & Chatham station, in one signal cabin. A new building to accommodate it has been erected on a site between the two main stations, and consists of a brick building, 113 feet long and 14 ft. 7 in. wide, constructed in three storeys. The top storey accommodates the power frame, the length of which is over 64 feet, while the interlocking extends down to the floor below. The remainder of the building accommodates relays, batteries, appliances, etc. Above the frame on the top storey are two large spot-light track diagrams, each 18 feet long, together with indicators, train describers, and other fittings and appliances as are necessary.

Lay-out and signals.

The track plan reproduced shows the whole of the area which is controlled by this cabin. The track diagram in the cabin corresponds thereto, with the addition of the spot lights controlled by the respective track circuits. As will be seen, there are 11 platform lines in the « Brighton » station — four in the Low Level station, and six, with one through line, in the South Eastern & Chatham main

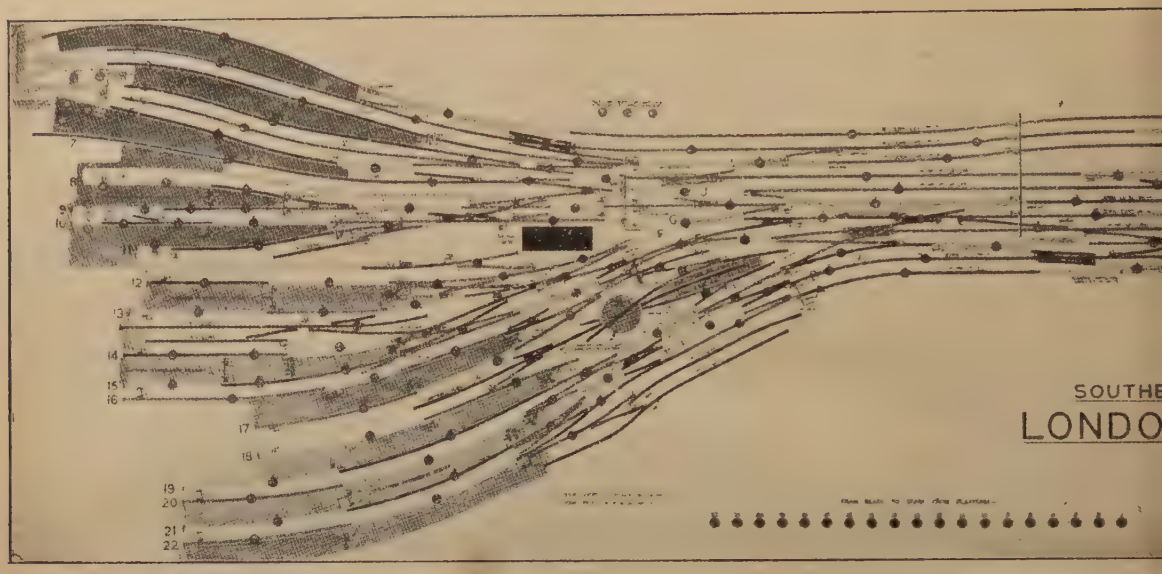


Fig. 1. — Illuminated signal diagram (with

The two sections will be mounted as one diagram. Owi

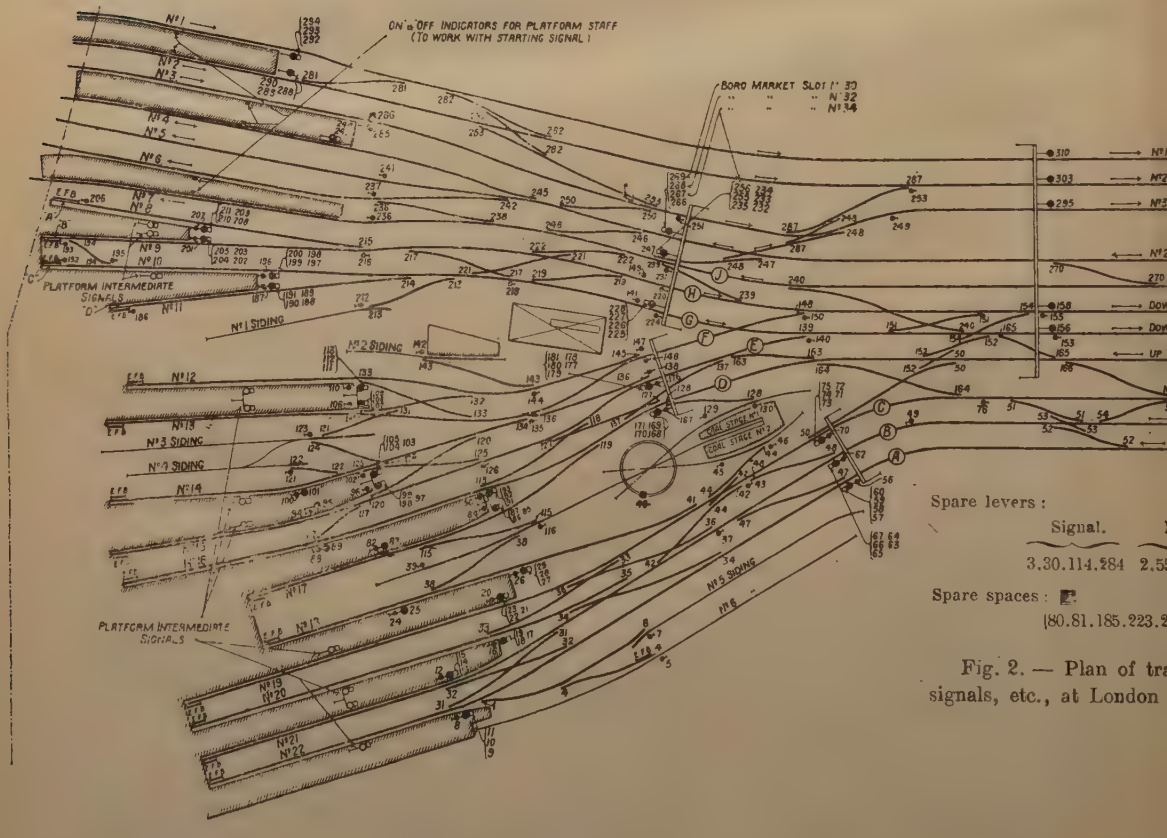
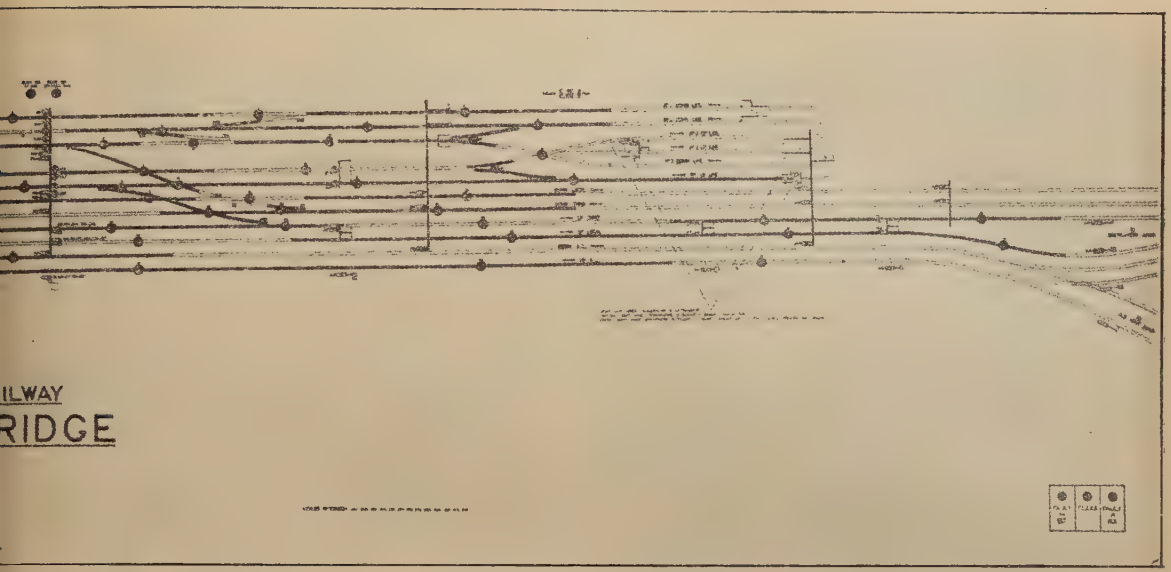


Fig. 2. — Plan of tra
signals, etc., at London



ng) prepared for placing above signal frame.

size of the frame two such diagrams are being provided.

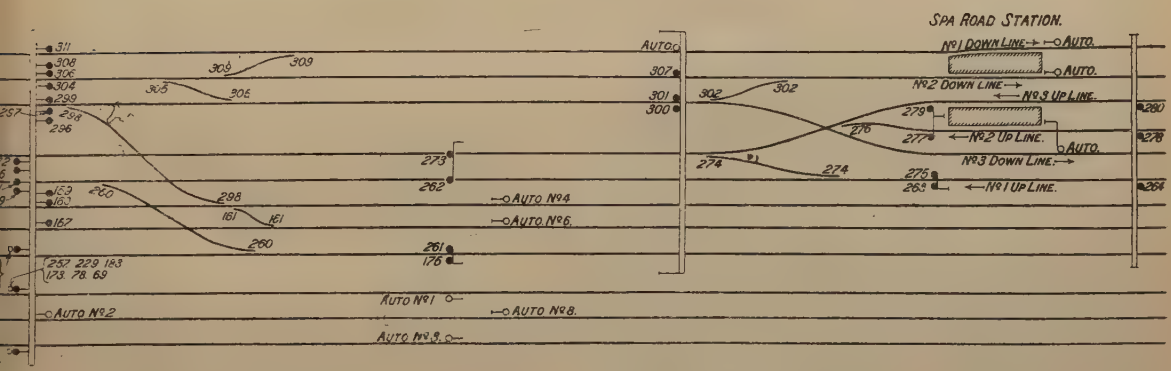


Fig. 2 (*continuation*), showing lines and signals onwards to Spa Road.

station, together with a few sidings, turntable and coal stage in the « Brighton » station, and a complex series of connections and interconnections. Beyond the station there are for some distance 11 tracks with other interconnections, and farther along still, adjacent to where Spa Road station used to be, there are 12 tracks. The new signal cabin therefore controls all traffic movements in the « Brighton » and Low Level stations and at the eastern end of the South Eastern & Chatham main station. As the latter is a through station, traffic working at the western end is under the control of Borough Market cabin, where, also, a power frame is installed, though 36 levers suffice in this case. The new main cabin thus replaces four signal-boxes, involving 574 mechanical levers. Of these, London

Fig. 3. — General view of frame at builder's works.

Bridge North and London Bridge « B » are large boxes, London Bridge South and London Bridge « C » being smaller. The new Borough Market signal-box replaces the present Borough Market and London Bridge « A » boxes, which together have 62 mechanical levers. Formerly the services of about 50 signalmen and 12 signal lads were utilised, whereas the new box is worked by 16 men with eight signal lads. About 2 000 trains daily have to be handled, together with a certain amount of station and engine shunting in the « Brighton » and Low Level stations.

The whole of the area concerned has been continuously track-circuited at 75 cycles A. C., these tracks controlling :

a) Signal lamp circuits;
b) Point lever locks, normal and reverse;
c) Front signal lever locks, except in the case of platform starting signals;
d) Signal lever back lock.

The track circuits are of two types : single rail, condenser fed; and double rail, reactance fed, with resonated impedence bonds.

Relays and locking circuits.

As the signalling is to some extent automatic, particularly beyond station connections, the relays for the automatic and the first of the series of controlled signals, together with those for track circuits over 500 yards from the box, are accommodated on local sites; all others are, however, placed in the signal cabin. They are classified as follows :

a) Track relays, 2-element vane type, local coil 110 volts, track coil 1-2 volts for reactance feed, 110 volts for condenser feed;
b) Point indicator relays, 3-position, 2-element, local and feed coils, 110 volts.

The locking circuits are operated at

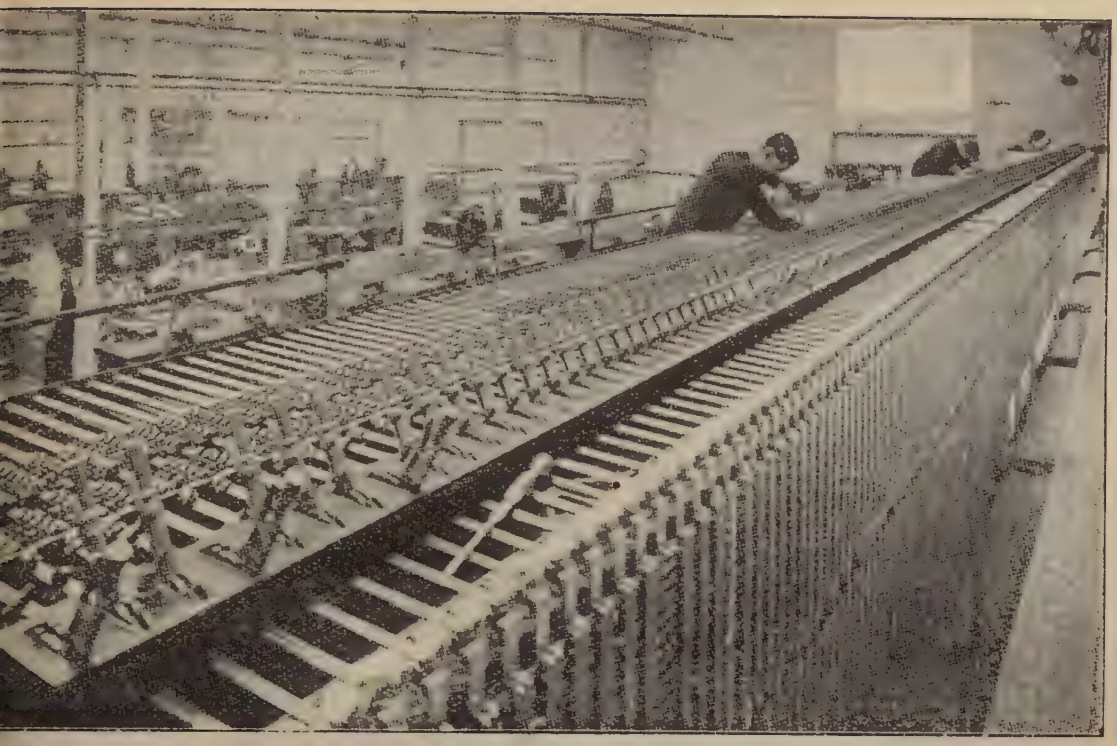


Fig. 4. — General view, showing frame under mechanical tests prior to wiring, etc.

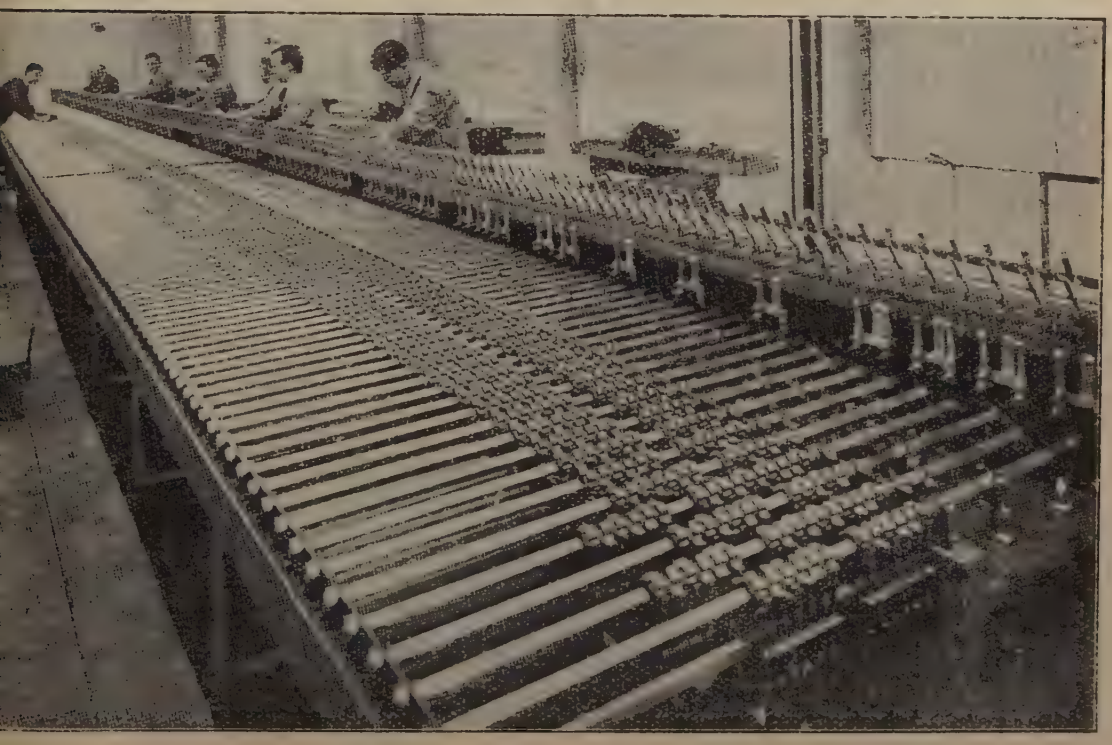


Fig. 5. — Another view of frame, showing also mechanical vertical interlocking.

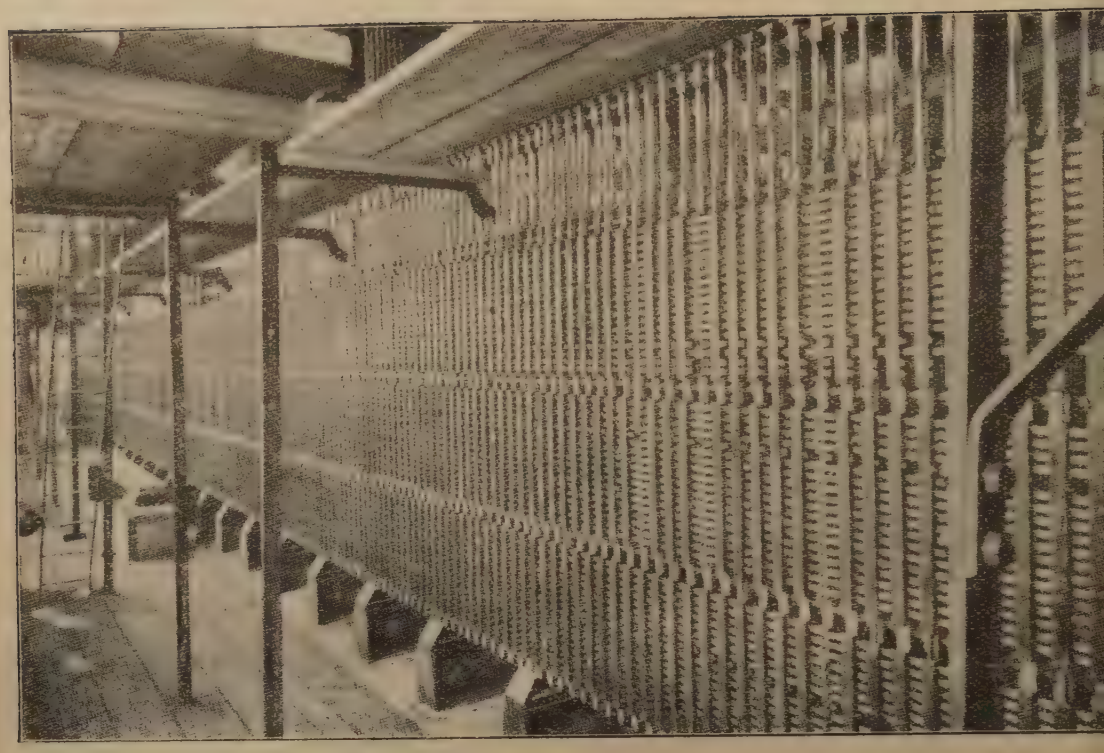


Fig. 6. — View of mechanical interlocking below frame.

110 volts A. C., and consist of the following :

a) Front locks, circuits energised by the closing of the appropriate relay contacts, *i. e.*, track circuits and point detectors;

b) Check locks on point levers, normal and reverse, operated through track and point detector relays. Check lock on replacing stroke of signal levers, circuits energised by signal returning to danger;

c) Signals back locks energised by appropriate track circuits clear.

The points are electrically operated by 130-volt D. C. series machines, with double field windings for normal and reverse operation. They are operated from a battery charged by a motor generator run from the D. C. current rail. The signals are 4-aspect on the Eastern section, and 3-aspect on the Central section. Colour light signals have 24-watt double filament lamps, 12 volt, 75 cycle A. C. « Double yellow » and « green » signal aspects are controlled by relays of signals ahead. The section of line between Bricklayers' Arms and London Bridge is equipped with 3-aspect automatic signals on both roads; the remainder are controlled from London Bridge and Borough Market. The equipment of this section of the line results in the closing of Abbey Street, St. James Road, up Croydon Line, and South Bermondsey boxes.

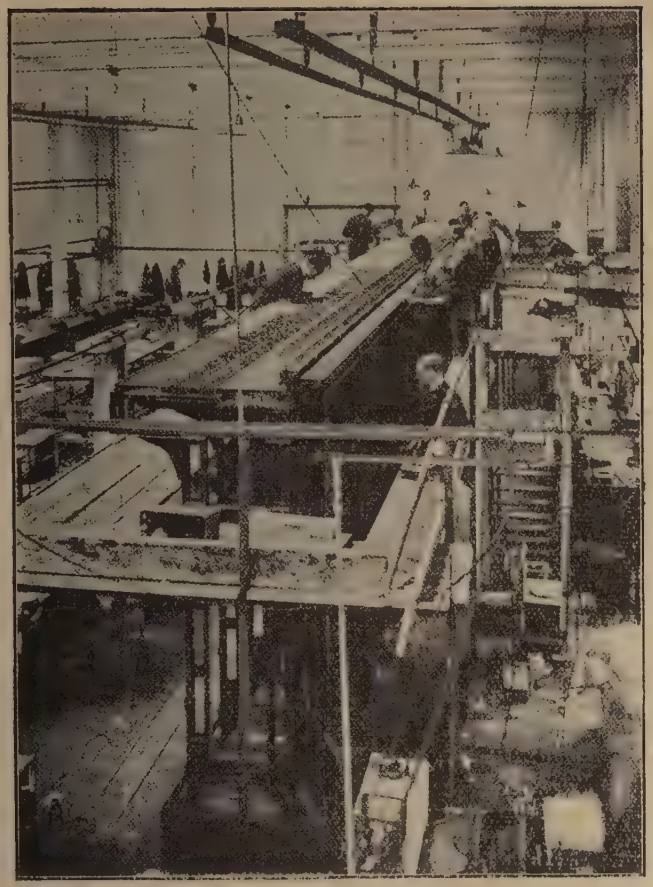


Fig. 7. — Another view of frame as erected for mechanical and interlocking tests.

Fig. 8. — Point motors and colour light and route-indicating signals receiving final touches.

The following special features may be mentioned :

a) Automatic signals do not give the « clear » indication unless either :

1. The signal ahead is properly returned to danger behind the last train, or
2. The line is clear for an appropriate distance ahead.

b) Approach locking. When the train has approached within a predetermined distance of the signal, the road cannot be altered until the train has passed clear of the junction ahead concerned;

c) Approach control. Wherever a speed restriction is necessary for cross-over roads, etc., a signal remains at danger, even though the lever is pulled, until the train has arrived within a pre-determined distance of the signal;

d) All signals aspects and route indications, and the normal or reverse position of the points, are shown by miniature lamps behind the levers in the frame;

e) The illuminated diagrams are fitted with leakage indicators which show a breakdown in insulation resistance to earth on either the positives or the negatives of the signalling wiring system. The three indication lamps can be seen in a corner of the diagram illustrated above (fig. 1).

Demonstration and tests at builders' works.

As erected at Chippenham, the frame was, of course, unencased and had not been wired. This part of the work must necessarily be done on the site, and was carried out by the signal staff of the Southern Railway, who have also been responsible for the erection of the signals and fitting of point machines, in conjunction with the staff of the Engineer's Department, which has also been concerned with the laying of conductor rails on tracks newly equipped for electric traction and for certain track alterations. The views reproduced show the complexity of the frame and the notable character of the mechanical interlocking involved. The frame itself is 64 feet long and represents a weight of about 23 tons. On the occasion of our visit the frame was undergoing severe interlocking tests and final touches prior to dismantling for transfer to London. Work was also in hand on the light signals, point machines, relays and other appliances, which are being supplied by the Westinghouse Brake & Saxby Signal Company.

[625 .258 (.75) & 656 .259 (.75)]

Yard costs cut 17 per cent.

Figs. 1 to 4, pp. 878 and 879.

(*Railway Age.*)

On 8 February 1926, the Illinois Central placed in service at East St. Louis, Ill., a gravity yard equipped with electrically operated car retarders. As a result of the efficient operation of these facilities, the average cost per car handled has been reduced from 53.27 cents in 1925 to 44.18 cents in 1927, a decrease of 17 %. The total yard switching expense was $475 970 in 1925 and $415 643 in 1927, while the number of cars handled increased from 893 562 in 1925 to 943 425 in 1927. In other words, 49 863 more cars were handled in 1927 than in 1925, while the total expense decreased 12.7 %. During the same period, the revenue switch engine hours were reduced from 62 636 to 48 149 and the number of cars handled per revenue switch engine hour was increased from 14.3 in 1925 to 19.6 in 1927.

The saving represented by the above figures does not include the more intangible savings effected by the reduction in damage claims, the complete elimination of personal injuries, the reduction in damage to equipment and the increased speed with which cars move through the yard.

These results are particularly interesting, since they seem to disprove the more or less general opinion that a hump yard installation is only justified in places where the business handled averages 2 000 or more cars per day. The number of cars actually humped at East St. Louis yard in 1927 was 349 330 or somewhat less than 1 000 cars per day. The lay-out of the yard is also at variance with the usual design of a gravity yard handling cars in both directions. The normal lay-out in such cases, as reflected in some of the largest yards in the country, is to have two complete sets of yards, each set consisting of a receiving yard, classification yard and departure yard, for one direction. At East St. Louis, as shown in the accompanying diagram (fig. 1), and explained in more detail later, the business in both directions is brought into one receiving yard, taken over one hump into the same classification yard and the departure yards are dispensed with entirely.

The original yard at East St. Louis was established to take care of the interchange with connecting lines at that point and to serve as the breaking point for many southbound manifest trains, the heavy coal traffic moving north and west and much mixed freight traffic for other roads. Most of the interchange traffic is handled through the medium of the Terminal Railroad Association of St. Louis, for which line three separate classifications are made, depending upon the trunk line to which the freight is to be delivered.

The receiving yard is 4 300 feet long and contains 13 tracks, with a total capacity of 1 050 cars. The classification yard is about 4 900 feet long and contains 26 tracks. Of these, 20 are used for classification purposes, having a total

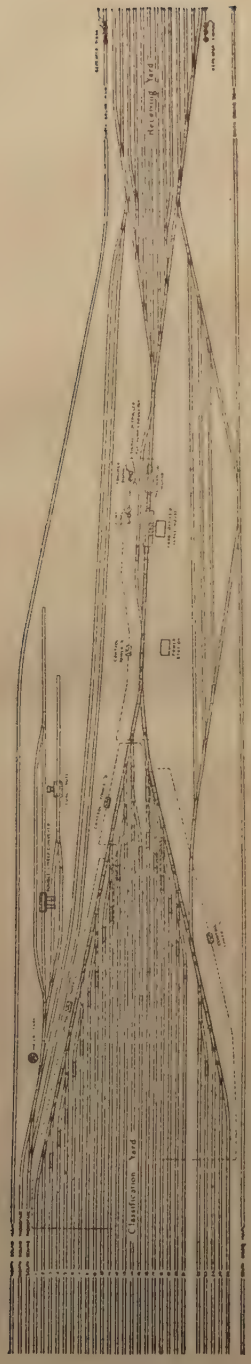


Fig. 1.

Only one set of yards is used for classification in both directions.

capacity of 1 975 cars. A double-track thoroughfare for yard and light engines is provided and the north and southbound main tracks are on the east and west sides of the yards respectively.

The car retarder installation, which was installed in this yard by the General Railway Signal Company, was described in the *Railway Age* of 6 March 1926, page 593. One two-indication and three three-indication color-light signals are used in controlling the movements of the humping and trimmer engines. The humping signals display four indications and the trimmer signals two.

The yard is equipped with a three-section mechanical hump, which is adjustable to compensate for extremes in weather conditions. Illumination is provided by three 4 000-watt flood-lights, situated on 120-foot towers. A 72-foot, 150-ton plate fulcrum automatic track scale has been installed near the top of the hump and about 40 % of the cars humped are weighed.

Operating methods and results

As stated previously, all traffic, both northbound and southbound, is handled through the same receiving and classification yards. Northbound trains are brought directly into the receiving yard and the cars are humped into the series of tracks at the west side of the classification yard, where trains are built up for movement north on northbound main track, which parallels the classification yard on the east. Cars arriving on the southbound main are brought into the receiving yard along the east side of the classification yard, and thence taken over a lead, which leaves the main line opposite the hump, into the receiving yard. They are then pushed over the hump into the series of tracks on the east side of the classification yard, built into trains and taken out to the southbound main over a lead which leaves

Fig. 2. — Looking towards the hump from the classification yard.

Fig. 3. — Two classification leads are used.

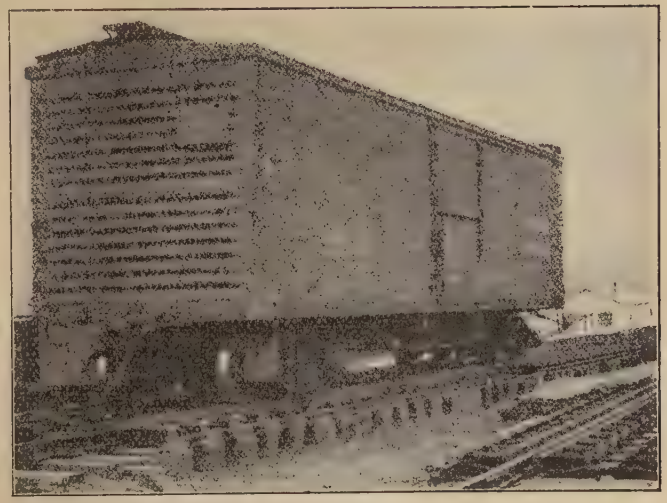


Fig. 4. — Retarding a car in the main lead retarder.

TABLE I.

Cars handled over hump.

5 January.			6 January.		
Number of cars.	Time high.	Time over.	Number of cars.	Time high.	Time over.
40	8 45	9 10	50	8 55	9 15
46	9 15	9 25	30	9 10	9 18
42	9 50	10 05	40	9 35	9 45
46	10 10	10 22	50	10 00	10 18
40	10 28	10 40	46	10 18	10 28
22	10 45	10 50	66	10 35	10 50
32	10 55	11 03	50	11 05	11 18
47	11 10	11 20	47	11 30	11 45
40	11 25	11 35	46	11 50	12 05
40	11 40	11 48	85	12 15	12 30
40	11 53	12 05	46	12 35	12 48
100	12 10	12 40	73	12 58	1 08
49	1 00	1 12	49	1 40	1 50
40	1 18	1 30	46	1 58	2 10
30	1 55	2 05	46	2 30	2 40
40	2 50	2 58	44	2 45	2 55
55	2 25	2 45	40	3 00	3 10
40	3 03	3 10	46	3 20	3 30
38	3 15	3 22	70	3 45	4 00
23	3 30	3 40	56	4 08	4 22
90	3 50	4 12	40	4 25	4 34
25	4 20	4 28	25	4 42	4 50
60	4 32	4 45	26	4 55	5 00
44	5 10	5 20	18	5 15	5 20
48	5 30	5 40	40	5 40	5 50
1 167 cars.			1 175 cars.		

the eastern ladder track into the classification yard.

As each inbound freight train arrives in the receiving yard, its conductor delivers the waybills to the office at the north end of the receiving yard. After the train has been checked and inspected, switch lists are prepared for the guidance of the hump conductor and the retarder operators. If it should be necessary to make any changes or corrections in the list, the information is broadcast to all concerned by means of intercommunicating « loud-speakers ».

A check of humping operations, made on 5-6 January 1928, revealed an efficient performance. The details of the work performed on these two days are given in table I. On 6 January, 1 175 cars were humped in a total elapsed time of 8 h. 55 m. Deducting the usual 20-minute lunch period, this is at the rate of 2 1/3 cars per minute for the entire shift. Eliminating the intervals between cuts, it will be noted that these 1 175 cars were handled in 267 minutes actual humping time, or 4.4 cars per minute. Between 12.15 and 12.30 p.m., 85 cars were humped, or 5 2/3 cars per minute and a humping speed of five or more cars per minute was attained at other intervals throughout the day. Other interesting performances during the same period included 28 cars humped in 3 minutes, on 4 January, or 9 1/3 cars per minute; on 7 January, 86 cars were humped in 10 minutes, or 8.6 cars per minute, and on 8 January, 80 cars were humped in 12 minutes or 6 2/3 cars per minute.

Table II gives the total yard switching expense by months for 1925, 1926 and 1927. In studying this table and also the following detailed figures, the differences in the number of cars handled should be borne in mind. The yard accommodated 12 568 more cars in 1926 than in 1925, and 37 925 more cars in 1927 than in 1926, or 49 863 more cars in 1927 than in 1925.

TABLE II.

Total yard switching expenses, 1925-1926-1927.

—	1925	1926	1927
January	$50 551	$45 835	$39 347
February	41 511	38 466	36 382
March	39 007	39 928	39 338
April	35 437	35 519	32 246
May	35 929	33 679	30 958
June	34 715	34 410	29 813
July	35 177	35 083	35 407
August	38 015	36 040	32 669
September	38 548	36 432	34 190
October	40 853	39 162	35 265
November	42 144	39 654	34 397
December	45 276	41 076	35 631
Total	$475 970	$455 283	$415 643
Average per month	39 764	37 940	34 637

The principal reductions made in switching expense were, of course, in the wages of yard conductors, brakemen and enginemen. These wages totaled $254 899 in 1925, $ 222 842 in 1926 and $209 620 in 1927. The wages of the retarder operators, amounting to $22 954 in 1926 and $18 216 in 1927, should of

TABLE III. — Comparative details of yard operation.

	Cars handled.			Revenue switch engine hours.			Cars handled per revenue switching engine hour.			Cost per car handled (cents).		
	1925	1926	1927	1925	1926	1927	1925	1926	1927	1925	1926	1927
January	84 411	77 224	76 608	6 705	5 455	4 557	12.6	14.2	16.8	59.89	59.35	51.36
February	69 309	68 464	80 042	5 196	4 382	4 158	13.3	15.6	19.3	59.89	56.18	45.45
March	70 907	74 828	92 848	5 096	4 559	4 044	13.9	16.4	20.0	55.01	53.36	42.37
April	67 657	72 325	67 413	4 429	4 030	3 807	15.3	17.9	17.7	52.38	49.11	47.83
May	73 894	71 457	71 345	4 575	3 866	3 790	15.5	18.5	18.8	48.62	47.13	43.39
June	69 677	70 849	70 424	4 468	3 949	3 647	15.6	17.9	19.3	49.82	48.56	42.33
July	70 816	72 457	77 432	4 728	4 020	3 725	15.0	18.0	20.8	49.67	48.42	45.73
August	70 193	77 431	87 799	5 192	4 063	3 886	13.5	19.1	22.6	54.16	46.54	37.21
September	77 062	78 890	86 065	5 205	3 988	3 987	14.8	19.8	21.6	50.02	46.18	39.72
October	81 990	86 645	88 142	5 742	4 257	4 068	14.2	20.3	21.7	48.37	45.20	40.01
November	76 729	77 814	75 192	5 510	4 448	3 824	13.9	17.5	19.7	54.93	50.96	47.33
December	78 945	77 746	70 105	5 580	4 636	4 036	14.1	16.8	17.4	57.35	52.83	50.04
Average per month	74 464	75 511	78 619	5 219	4 304	4 011	14.3	17.5	19.6	53.27	50.24	44.18

course be added to the figures for those years before the wage reduction can be computed, but even after this is added, the wage reduction in these items amounted to $9 103 in 1926 and $27 063 in 1927 as compared with 1925. Yard clerks' wages amounted to $63 769 in 1925 and $54 330 in 1927, a decrease of $9 439.

The total revenue switch engine hours amounted to 62 636 in 1925, 51 653 in 1926 and 48 129 in 1927. The resulting saving in fuel consumption was $1 035 in 1926 and $7 230 is 1927. The steadily increasing efficiency of the yard as the men and officers become more familiar with the new operating methods is reflected in the decreasing cost per car handled. In August 1925, for example, this cost was 54.16 cents, in August 1926, 46.54 cents and August 1927, 37.21 cents, a reduction of 16.95 cents per car or 31.3 % in August 1927, compared with the same month in 1925. During the same months, the average number of cars handled per switch engine hour increased materially being 13.5 in August 1925, 19.1 in 1926, and 22.6 in 1927, the latter being an increase of 9.1 cars per hour, or 60.7 %.

The largest saving in the total yard switching expense for any one month was in January 1927, when the total expenses amounted to $39 347 as compared with $50 551 for the same month in 1925, a saving of $11 204 during one month's operations.

Table III gives the details concerning the number of cars handled, the average cost per car, the number of revenue switch engine hours and the number of cars handled per switch engine hour.

As the men and officers grow more familiar with the operating details, the work and the supervision show a material improvement, which is reflected in the statistics. Since the yard was not installed in its present form until 1 Fe-

bruary 1926, the following figures represent the last 11 months of each year only. During this period of 1926, the total yard switching expense was $409 449 as compared with $376 276 in 1927, or an average per month of $37 222 and $34 207 respectively. In addition, 37 911 more cars were handled in 1927 than in 1926, or 866 817 as compared with 828 906. The average cost per car handled shows a material decrease, being 49.49 cents in 1926 and 43.49 cents in 1927, or a reduction of 6 cents per car.

Despite the increased business, revenue switch engine hours were reduced from 46 198 in 1926 to 43 572 in 1927, the cost per revenue switch engine hour from $8.86 to $8.66 and the cars handled per revenue switch engine hour were increased from 17.9 to 19.9. Among the other economies effected in 1927, was the discontinuance of the hump pusher engine early in April. In 1926, a total of 5 959 hours was worked by the hump pusher, as compared with 936 hours in 1927. These figures are not included in the revenue switch engine hours. In other words, a reduction of 7 649 hours was effected in switch engine hours, although 37 911 more cars were handled.

MISCELLANEOUS INFORMATION

[624 .92 & 669 .1]

1. Silicon steel for constructional use.

The German steel industry is at the present time manufacturing a silicon steel possessing remarkable qualities as constructional steel for building purposes. The Doctor Engineer Koppenberg, Riesa, devotes to it an article containing much interesting information in the review *Der Bauingenieur*, number 18, 1928.

The successful manufacture of this steel in the Martin furnace has required much trouble and has taken a long time.

Its average chemical composition is :

C : 0.1 to 0.18 %;
Mn : 0.8 to 1.00 %;
Si : 0.7 to 1.00 %;
Ph : not exceeding 0.06 %;
S : not exceeding 0.05 %;

For large sections the carbon content has to be raised to 0.2 % to get the minimum apparent limit of elasticity.

The average physical tests taken over a year's manufacture have been :

Apparent elastic limit (Streckgrenze) : 39 kgr. per mm² (36-44 kgr. per mm²) [24.76 English tons per square inch (22.86 to 27.94) ;

Tensile strength : 55 kgr. (49-62) [34.92 English tons per square inch (31.11 to 39.37)] ;

Elongation at fracture : 23 % (20-26 %) ;

Reduction of area at fracture : 55 % (50-60 %).

The specification drawn up by agreement between the German steel makers (Verein Deutscher Eisenhüttenleute), the German constructional firms (Eisenbau Verband) and the State Railways requires :

Minimum apparent elastic limit : 36 kgr. per mm² (22.86 English tons per square inch) ; [35 kgr. (22.22 English tons per square inch) for thickness above 18 mm. (45/64 inch)].

Tensile strength : 50-62 kgr. per mm² (31.75 to 39.37 English tons per square inch) ; for thickness greater than 18 mm. (45/64 inch) up to 64 kgr. per mm² (40.63 English tons per square inch).

Elongation : 20 %.

Cold bend : 2d up to 18 mm. (45/64 inch) and 3d above 18 mm.

The strength under shock of the silicon steel is about the same as that of ordinary mild steel (St 37) ; it is less readily welded owing to the high silicon content. Upsetting tests have also been satisfactory (one-third of the length).

The modulus of elasticity E is the same for silicon steel as for the St 37 and St 48 steels.

The use of parts in silicon steel in building requires greater precautions than with ordinary mild steel; rivets should be driven at a suitable temperature; care must be taken to avoid working at a blue heat, etc.

Taking into account all unfavourable conditions the State Railways have fixed the maximum working strength of the silicon steel at 2 100 kgr. per cm² (13.33 English tons per square inch), that is, 50 % above the ordinary St 37 steel. The reduction in weight so obtained in bridges of medium or long span reaches 30 %. When the higher price of this steel is taken into account, there is still a very appreciable saving for structures exceeding certain spans.

During the first year of manufacture of the silicon steel — in 1927 — the German railways built a certain number of railway bridges of it. Amongst others, we may quote the bridge over the Drage near Kreur, that over the Oder near Oppeln, containing in all 12 500 t. (12 300 English tons) of steel work.

Tests made are all in favour of an extended use of this steel.

Silicon steel also offers advantages in ship building by the reduction of the dead weight carried.

In railway work the State Railways have also considered its application in the construction of high capacity wagons. It will probably be possible to reduce the tare weight of 60-ton capacity wagons to 19 or 20 tons.

The German Steel Trade foresees that in the future there will be only two steels used for constructional purposes, namely, the ordinary mild St 37 steel for small spans and St. Si steel for large and moderate spans.

R. D.

[625 .243 (.485)]

2. — Railway wagons with collapsible roofs, Swedish State Railways,

By A. PAULSON,
SUPERINTENDENT OF THE SWEDISH STATE RAILWAYS.

Figs. 1 and 2, p. 886.

(*The Railway Gazette.*)

The cost of railway transport includes many factors, of which the capital invested in the rolling-stock is important. Suitably designed rolling-stock, which can be used for various classes of goods and so avoid empty haulage as much as possible, yields better interest than unsuitably designed rolling-stock.

The generally good economical conditions which prevailed at the end of the last, and the beginning, of the present century, may in their way have contributed to the fact that the rolling-stock of the railways has become rather heterogeneously composed. Besides certain indispensable special models such as ore trucks, refrigerated and heated vans, the last of which, as regards the Swedish State Railways, amount to only 2 1/2 % of the whole stock, there were built several classes of open and covered trucks, each designed for a certain kind of traffic.

As many of these vehicles were not suitable for other classes of traffic a considerable amount of empty mileage was necessary and, as in other countries, it became apparent that the standardisation of the wagon stock would be beneficial in many directions. The Swedish State Railways have for some time been engaged on a programme of standardising the rolling-stock. It was found after investigation that lime could quite safely be transported in trucks used also for other traffic, and special lime trucks have practically been abandoned, a fact that has eliminated a good deal of empty mileage. Low-sided wooden and timber trucks have also been abolished, the aim being gradually to reach one type of covered and one type of open truck with plate flaps. As a result of their efforts the State Railways now have only nine types of open and covered trucks, and it is hoped that this number will soon be reduced considerably.

A difficulty in the way of realising a completely rational programme of standardisation exists in the different characteristics of open and covered vehicles, and efforts have been directed to the development of a covered vehicle so constructed that it could be loaded also as an open wagon, thus combining in one the best qualities of both types of vehicles. The problem has now been solved in Sweden by the provision of a wagon with a collapsible roof, similar to that illustrated, and the Railway Board have fitted 15 vehicles with such roofs in order to give the invention a thorough trial. The inventor is the Chief Engineer, Jonas Jonsson, of Vansbro, Sweden. The roof is longitudinally divided and both parts are collapsible. It consists of two shutters worked by two arms which are fixed to a common axle at both ends of the truck. The shutters are movable outwards and are manipulated by a handle which, through a suitable reduction

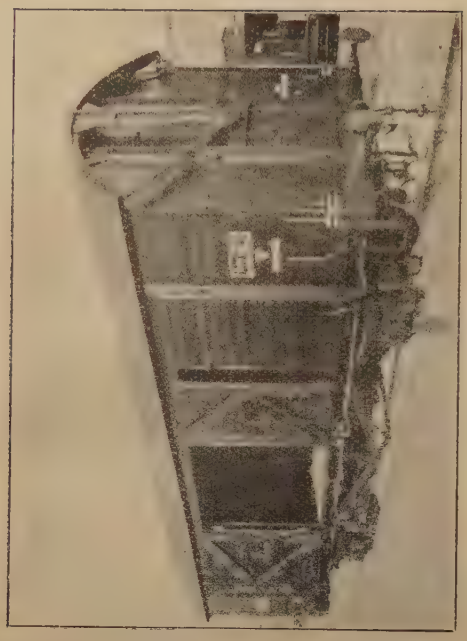


Fig. 2. — Wagon with roof in closed position ready for side loading.

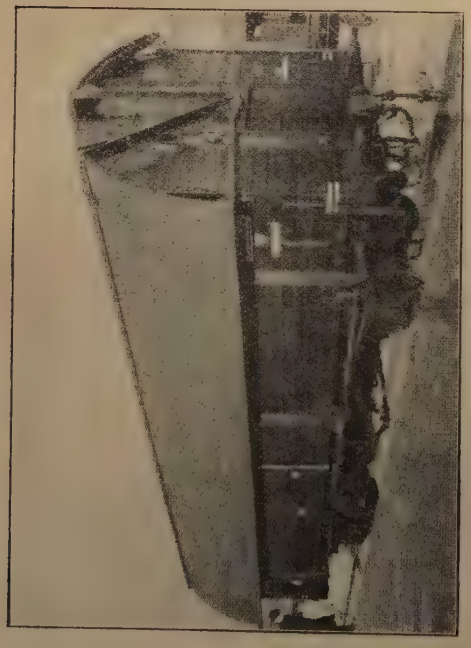


Fig. 1. — Wagon with roof partly open for top loading.

gearing by means of a worm wheel, operates a system of cog-wheels, which turn an axle, situated immediately under the roof along the vehicle and lying on the bearings both at the ends and at two points at about one-third of the length. On the axle are two cog-wheels, one at each end, which gear into a toothed segment situated on the down side of the roof. Both the lowering and raising are easily done by one person and take only two minutes. An angle-iron which automatically falls over the joint between the shutters effectively keeps out water. During the year experiments have proceeded neither rain nor snow has penetrated into the trucks. On the sides roomy doors have been attached for the loading of piece-goods, etc., and on the end walls diagonally placed wickets have been arranged for the loading of wood-goods, pipes, etc.

Without touching further upon the economical importance of the introduction of this type of vehicle into the railways, I will only mention that if the invention fulfils its promise, the rolling-stock of the Swedish State Railways can be reduced considerably, with its present traffic capacity maintained. The savings which thus could be made annually, amount to considerable sums. But not only the working expenses of railways can be saved in this way. The consignors and consignees would also obtain direct and indirect advantage by the use of this type of truck.

The trucks can be loaded and unloaded with the aid of cranes, *e. g.*, piece-goods, corn, flour, cement, wood-pulp, etc., can be taken from the hold of a ship by means of a crane on the quay or its own winch directly into the truck, or *vice versa*, and all this with a minimum of manual work. Planed wood can, irrespective of its length, be loaded into a covered truck through the wickets at the ends. Thus considerable damage, which is often caused to such wood through water or through the shifting of the load on an open truck, will be eliminated.

Sheets will become practically superfluous, a direct advantage both to the railway and to the consignors and consignees.

The first fifteen trucks have travelled

97 759 km. (60 746 miles) loaded, against 17 452 km. (10 844 miles) empty, the empty running thus being 15 % of the total 115 211 km. (71 590 miles) so far covered.

[621 .132.8 (.45) & 621 .133.1 (.43)]

3. — Pulverized coal burning locomotive built in Germany.

By Dr. Alfred GRADENWITZ.

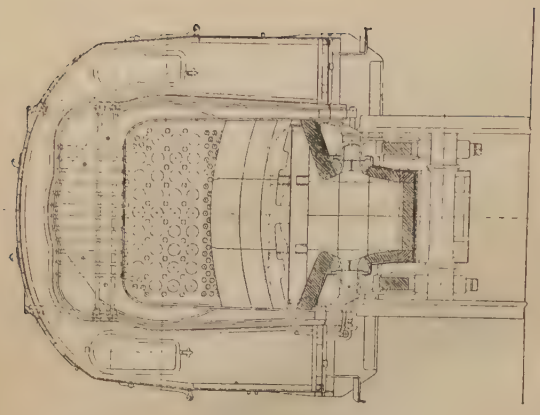
Figs. 3 and 4, pp. 887 to 889.

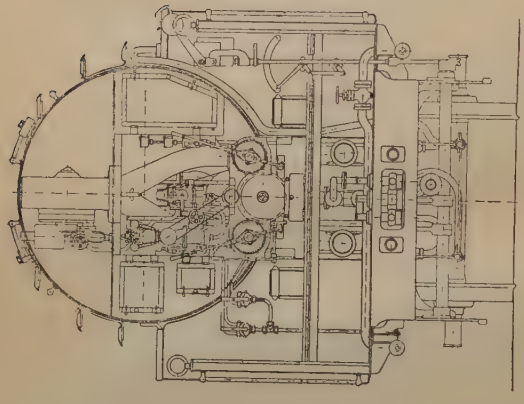
(From the *Railway Age.*)

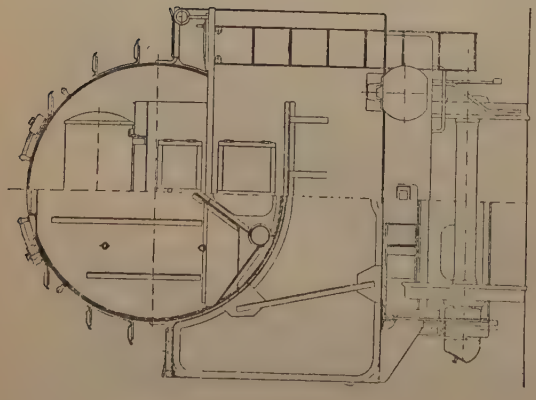
In 1924 the Allgemeine Elektricitäts Gesellschaft (A. E. G.), Hennigsdorf, Berlin, Germany, started developing a pulverized coal firebox for locomotives. A standard freight locomotive boiler was removed from a locomotive operated by the German State Railways and installed in a shed located over a working pit. By the fall of 1926, this boiler had given such satisfactory service that the A. E. G. proceeded with the design of a pulverized coal burning locomotive. This locomotive was completed the first part of 1927 and placed in experimental freight service in the latter part of July of that year. Since that time the locomotive has been handling freight trains on the main line of the German State Railways between the two points, Berlin and Fuerstenberg, a suburb of Mecklenburg.

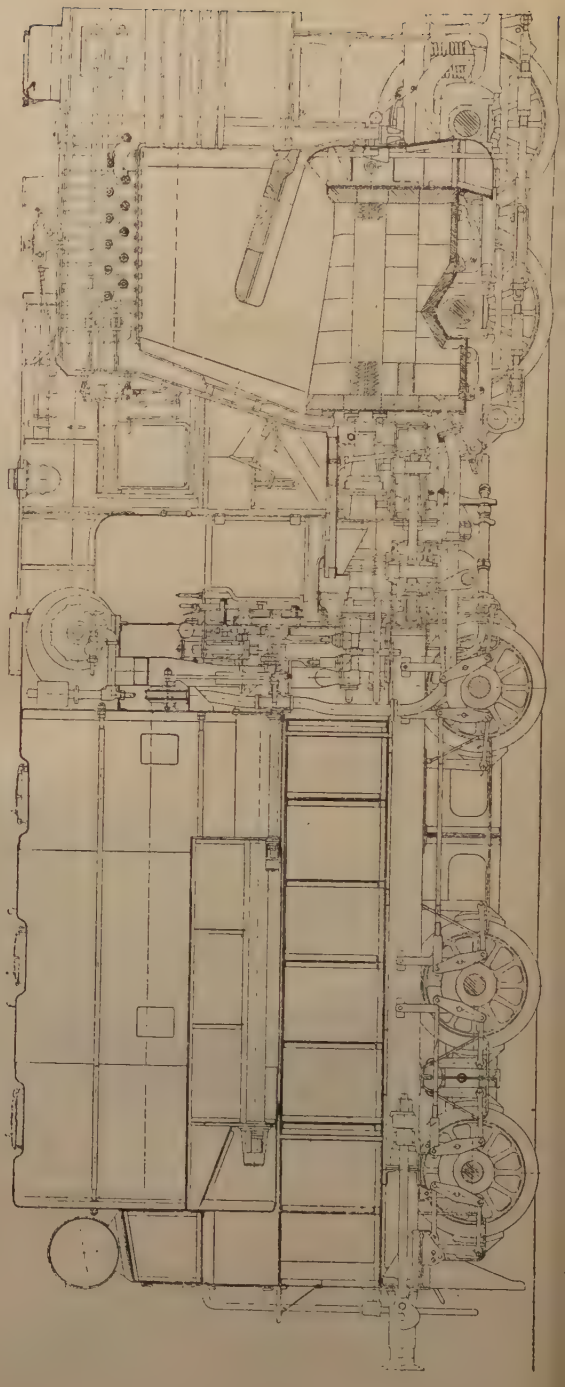
Fig. 3. — Pulverized coal burning locomotive built by the « Allgemeine Electricitäts Gesellschaft », Berlin.

As shown in one of the illustrations, this locomotive has the same external appearance as an ordinary locomotive with the exception of the tender, which is rather curiously shaped. The pulverized fuel is in a totally enclosed cylindrical horizontal container, and is mechanically conveyed to the firebox. The pulverized coal burns without smoke and with a total absence of sparks and, it is claimed, gives higher working efficiency than with ordinary









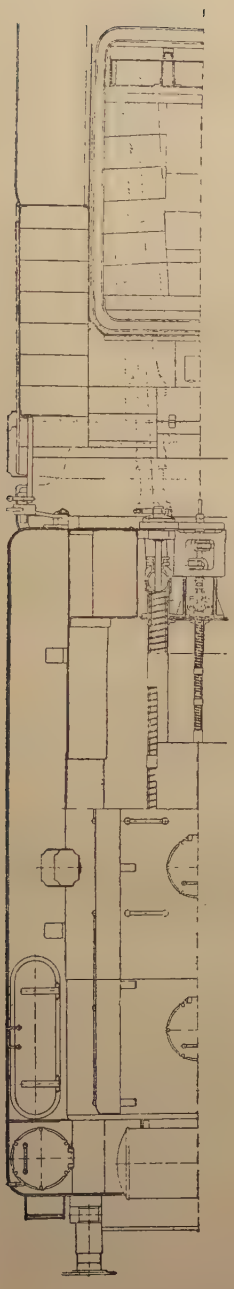


Fig. 4.
Erecting, plan and cross sections of the A. E. G. pulverized coal burning locomotive.

grate firing. Poor quality fuel, such as small and waste coal, lignite, peat, etc., can be successfully employed for pulverized coal-fired locomotives, and should effect considerable economies in service.

To ensure perfect combustion of all combustible matter, the flame of pulverized coal furnaces should be so controlled as to have the combustion process finished before the flame comes in contact with colder portions of the boiler. When this is not accomplished, any imperfectly burnt particles are separated in the form of coke.

Furthermore, in order to prevent the liquid ash particles from clinging to the brick arch and tubes, these particles should be cooled as rapidly as possible. Pulverized coal furnaces, in order to comply with these conditions should have ample heating surface while the time of combustion should be from one to three seconds.

On account of the limited space available, the installation of pulverized coal furnaces in locomotive boilers, meets with particular difficulties. The firebox with its water-cooled walls, which, in Europe, mostly consist of copper, will absorb a considerable amount of heat by radiation. This is in turn transferred to the boiler water.

This heat, however, is withdrawn from the flame during combustion. In fact, the possibilities of pulverized coal-fired locomotives have not, as a rule, been considered very hopefully. Locomotives of this type that have been built during the last ten years in the United States and Sweden, do not seem to have given satisfaction, no new units having been added during the past few years.

The efficiency of the boilers in the A. E. G. tests was raised from an initial figure of 67 % until a figure of 74.5 % was eventually reached. At the same time, the evaporation was raised to 14.32 lb. per square foot per hour. Difficulties connected with combustion and the production of slag were overcome by choosing convenient nozzles which subdivide the pulverized coal. Especially satisfactory results were obtained in connection with pulverized lignite, to the use of which the German State Railways attached considerable importance.

The tender and conveying system.

The pulverized coal tender has a bunker space of 424 cubic feet which accommodates a little over 5.9 tons of lignite. The bunker has the shape of a cylinder about 6.5 feet in diameter and 13 feet in length. The two conveying screws, supplying the pulverized coal to the locomotive nozzles, will handle a maximum of 4 629.7 lb. per hour at a maximum rate of 140 revolutions per minute, the amount of pulverized coal actually supplied being controlled by regulating the number of revolutions of the conveying screws. A blower supplying the primary air is driven by a simple steam turbine, its output being 7 H. P. as a maximum. This turbine had to be adopted on account of the very high speed required by the blower which operates up to 4 500 revolutions per minute. A small reciprocating steam engine is used to drive the slowly rotating conveying screws. At a pressure of 22.4 lb. per square inch this engine consumes 66 to 110 lb. of steam per hour. A small auxiliary burner at the rear wall of the ash pan serves as an igniter while the locomotive is standing or drifting, and is intended to make up for the radiation losses of the boiler and supplying steam for the air compressor so that the main furnace need not be operated for these auxiliaries. The auxiliary burner derives its air from a small blower driven by the steam engine on the tender. The surplus weight of the pulverized coal tender, as compared with a standard locomotive tender, is about 4 tons.

The air and pulverized coal mixture which is blown into the firebox contains only part of the combustion air in the form of primary air, the balance, *viz.* the secondary air being, as in any ordinary reciprocating steam engine locomotive, drawn in automatically from beneath the firebox by the action of the exhaust nozzle. The air and pulverized coal mixture is blown into two long nozzles facing each other from the sides of the pan below the firebox through which it is delivered in a large number of narrow bands. These strike one another in the centre of the furnace where a violent vortex is produced. The rising flames strike the preheated secondary air below the brick arch. The combustion chamber proper is surrounded with fire brick, with the arch above and the ash pan below, there being a possibility of heat radiation only on the side walls of the firebox. The hot gases at the end of the long arch are deflected upwards at a very high speed which causes the slag particles to be granulated on the crown sheet of the firebox, so that no slag clings to the ends of the tubes.

At the present time the A. E. G. has two pulverized coal locomotives of this design in operation which have, after a few trial runs at no load, been used for hauling freight trains on regular schedules over the Pankow-Heinersdorf - Loewenberg - Fuerstenberg - Mecklenburg-Strelitz line. A standard locomotive has always been included in the train to meet any emergency but no occasion when it has had to be used has ever arisen. The pulverized coal locomotive has frequently pulled trains of 1 300 tons, in addition to hauling the standard locomotive of 115 tons, whereas the maximum tonnage allowed over the entire line is only 1 100 tons. Furthermore, the pulverized coal locomotive could always better the regular schedule time.

It sometimes occurred during some of the test runs, that pulverized lignite and pit coal were stored in layers one above the other in the tender. This condition of changing from one kind of fuel to another in course of the trip never caused any inconvenience. Fluctuations in steam consumption could be easily taken care of under all fuel conditions.

The advantages claimed for the pulverized coal locomotive are as follows : The fuel cost is reduced by the possibility of using a lower grade of fuel, the possibility of using peat or lignite being a particularly valuable feature in German railroad operation. The most satisfactory results were obtained by using lignite, which contains a high percentage of volatile and can, therefore, be utilized to best advantage. The locomotive can use the kind of fuel most easily available and least expensive. The utilization of fuel is more complete than when used in a grate firebox, there being only half as much surplus air, the heating of which is a pure loss. A saving of 20 % is claim-

ed for the boiler, which can be fired more rapidly than that of grate firebox boilers. The simple control of the furnace in accordance with the actual steam consumption is particularly important. The time required for cleaning the fire is reduced to a minimum, while there are no fuel losses in discharging the slag.

[**621** .335 (.42) & **621** .43 (.42)]

4. — 500 B. H. P. oil-electric train for the London Midland & Scottish Railway.

Fig. 5, p. 892.

(From *The Engineer*.)

The oil-electric train, as applied to British railways, would seem to offer a field for development which falls between that of the already accepted steam or oil engine driven rail car and the quickly accelerated electric train, now so freely used for dense suburban traffic. With an oil-electric installation it becomes possible to employ a unit train of up to, say, 175 tons, with five to six coaches. As the power unit is installed in a separate compartment and is entirely electrically operated, the train can be driven equally well from either end, and difficulties in terminal working are thereby overcome. With regard to power output, such equipments may be well compared with that of a tank engine generally associated with passenger traffic of the type to which we have made reference. The available horsepower of the oil-electric generator set is greater than that of a tank engine at the lower speeds, and remains nearly constant at the higher speeds. In the article which follows we give a short description of a new 500 B.H.P. oil-electric train which, after undergoing an official inspection by London, Midland and Scottish Railway officials recently, ran a successful trial between Manchester and Blackpool. This train will, we are given to understand, be shortly put into service between Blackpool (Central) and Lytham.

The power unit.

A general view of the train is reproduced in figure 5. It is a four-coach unit, in which accommodation is provided for thirty-two first-class and 255 third-class passengers. Its length over the buffers is 247 ft. 3 in. and the width of the coaches overall is 9 ft. 6 in., with a height from the rail to the floor of the coach of 4 ft. 1 1/2 in. Unloaded — that is, without passengers and luggage — the train has a total weight of about 144 tons.

The oil engine driven generator set is housed in the first coach forward of the luggage compartment. There is a length of about 22 feet from the forward partition of the luggage compartment to the front end of the coach, a small portion of which is partitioned off to form the motorman's compartment. At the opposite end of the train there is a similar driving compartment. Duplicate fuel oil tanks, which contain sufficient oil for one day's service, are carried. There is also a tank for the engine cooling water, which is placed forward of the right-hand fuel tank. The tank is connected to a spiral tube type of cooler, which is arranged on the roof of the coach.

The engine is of an eight-cylinder unit of the Beardmore all-steel quick-running type, and was built at the oil engine works of William Beardmore & Co., Ltd., Parkhead, Glasgow. In general, the design is similar to that prepared by Mr. Alan Chorlton for the four-cylinder units built for the Canadian National Railway rail cars, described in the issues of *The Engineer* for 2 and 23 October 1925. For detailed features of construction, our readers may be referred to the first article above named.

The designed output of the unit we are at present considering is 500 B. H. P. at 900 revolutions per minute. Each cylinder has a bore of 8 1/4 inches with a stroke of 12 inches. By the extensive use of alloy steels it has been possible to produce an engine having a weight of only 14 1/2 lb. per B. H. P.

The engine crank case is mounted on a deep casting of special alloy steel, which forms the oil sump. The underside of this casting is bolted to the car sills, and the main casting

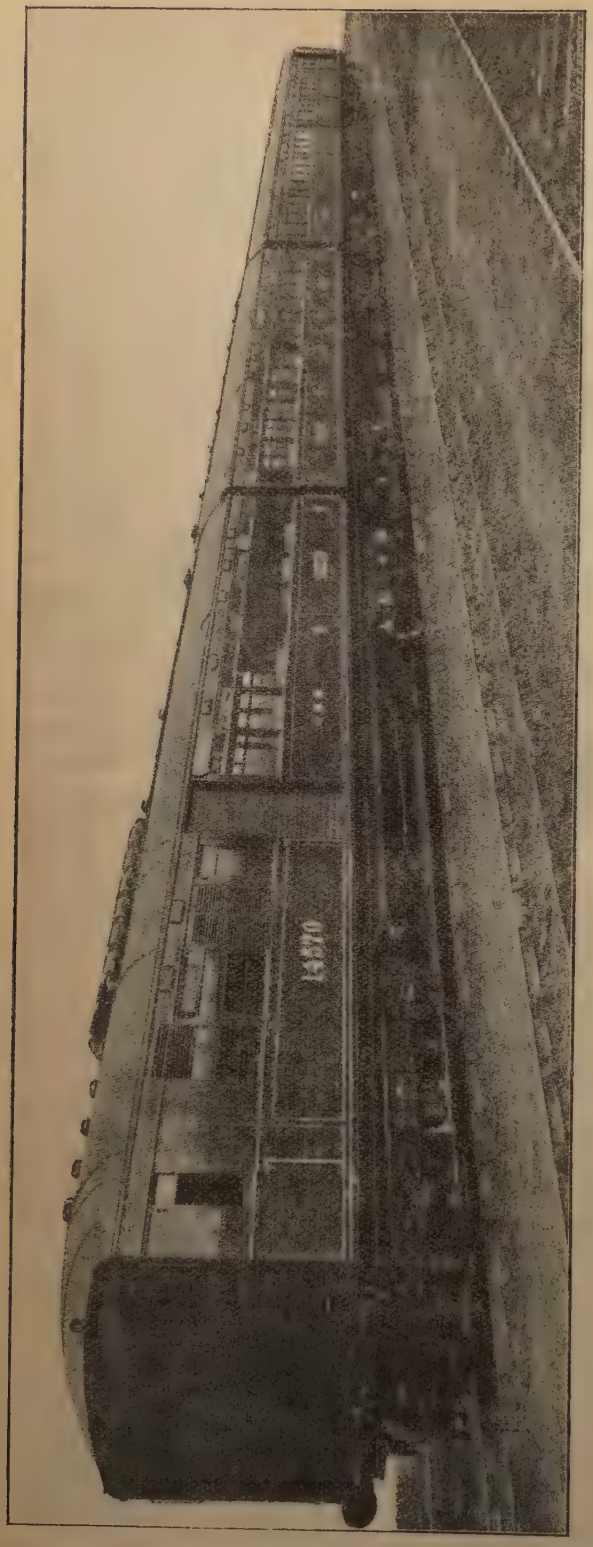


Fig. 5 — General view of four-coach 500 B. H. P. oil-electric train.

is extended to bolt up to the frame of the direct coupled electric generator. Each cylinder is furnished with two inlet and two exhaust valves with a centrally placed airless injection fuel atomiser. A primary oil pump maintains a low pressure on the suction side of the main fuel pump. There are four separate plungers, each of which serves two cylinders by means of a switch valve placed between the fuel pump delivery valve and the atomisers. The object of this valve is to time the injection of the fuel for the two separate cylinders served by the single plunger. As the injection period is timed, the engine output is controlled by varying the effective delivery stroke of the plunger by means of the earlier or later opening of a by-pass valve. Any surplus fuel is returned to the supply tank. The governor is of the totally enclosed type, and is so connected to the fuel pump controls that a small plus and minus speed variation is given at each of designed speeds of the engine. The engine is automatically controlled by electrical means. The four solenoid bobbins at the governor end of the unit, which are worked from the controllers, operate differential piston valves in an oil circuit, and by varying the oil pressure the governor is set in one of four different running positions. The engine is thus able to idle at 350 revolutions per minute, run at either 600 or 750 revolutions per minute, or at the maximum designed speed of 900 revolutions per minute, and at each setting the governor maintains a constant speed.

Lubrication is effected on the pressure system and the closed oil circuit includes a filter and oil cooler. « Monitor » valves are provided in both the lubricating oil and cooling water circuits, so that in the event of a failure taking place in either of these essential services, pilot lights are illuminated and give a warning in the driver's compartments. Arrangements are made whereby the engine can be stopped from either driving compartment, by energising a trip solenoid, which releases a shutter in the main air intake, and so cuts off the supply of air to the engine. The separate exhaust pipes are connected to a silencing tube which discharges the gases through a series of outlets carried through the roof of the motor coach.

The generator battery and traction motors.

The generator and exciter, together with the complete controls, were supplied by the English Electric Company, Ltd., and were built at Preston. The generator is of the direct-current traction type, and has a maximum designed output of 340 kw. on a one-hour rating, with an engine speed of 900 revolutions per minute. It is of the one-bearing type, and the exciter is overhung at the outboard end. The shunt winding of the generator is energised by the exciter or the battery according to the engine speed, and there is a series winding for decompounding which gives the unit a practically constant output characteristic at any speed of the working range. There is an adjustable resistance in the shunt field which is not used by the driver, but which can be set in the shed to meet special load conditions.

At engine speeds higher than 600 revolutions per minute the exciter is designed to function as an auxiliary generator. It supplies constant voltage current for battery charging and for auxiliary loads, such as lighting, control operation and driving the brake exhausters, if necessary. The constant voltage characteristic is obtained by a decompounding series winding. The battery charging current is at a maximum at the 900 revolutions per minute engine speed, and it diminishes with the speed until 600 revolutions per minute, when the battery floats across the exciter. There is an adjustable resistance in the shunt circuit for shed use. The normal designed output of the exciter is 7.75 kw. at 120 volts, the voltage at maximum engine speed being 147 volts, corresponding to the voltage of the battery when fully charged. A 60-cell battery, supplied by the D. P. Battery Company, Ltd., supplies current at 120 volts for control operation. The 60 D. P. K. L. 9 type cells have a 112-ampere-hour discharge capacity on a five-hour rating. As mentioned before, the battery is charged by the exciter and an automatic battery cut-out of the standard type is fitted.

The two motors are of the London-Watford type, and they are mounted on the bogie at the trailing end of the power coach. Each motor is rated at 280 B. H. P. on the one-hour rating at 580 volts, with a gear ratio of 18 to 60. They are connected to the generator in permanent parallel through a remote control circuit breaker. There are field tap connections for weakening the field in two steps, and a remote controlled reverser which can be operated from either driving positions determines the direction of the train. The main control gear is mounted on a framework over the main generator.

Starting and running controls.

The engine is started by operating the generator as a motor with battery current. After the battery switch is closed and current for general purposes is obtained, the generator field switch is also closed and then the starting switch. The battery current is limited by a resistance, and the starting switch is held closed until the engine fires. There is a spring release which opens the switch when the attendant releases the starting handle.

At either end of the train is the driver's compartment. The driving handle on the controller can be moved into one of seven positions, which provide for the following sequence of operations :

No. of position.	Description.	Operation.
1.	Off	Engine idles at 350 revolutions per minute.
2.	Transition.	Engine speeded up to 600 revolutions per minute; generator shunt field circuit opened; main circuit breaker closed.
3.	1st running notch	Generator shunt field circuit closed.
4.	2nd — —	Engine speeded up to 750 revolutions per minute.
5.	3rd — —	Engine speeded up to 900 revolutions per minute.
6.	4th — —	First field tap.
7.	5th — —	Second field tap.

In order to start the train the driver places his reverser key in the ahead — or reverse — position, and then moves the controller handle from position 1 to 2, at which he pauses a little while to allow the engine to speed up. He then moves the handle through positions 3, 4 and 5, and again pauses while the train accelerates. When a speed of 18 miles per hour has been reached the handle is placed in position 6, and position 7 corresponds to the normal running position with a speed of about 26 miles per hour. For inching and shunting, positions 3 to 7 may be employed. To shut off power, the handle is brought back to the off position, which slows down the engine to idling speed and shuts off power from the motors. The generator unit is only inspected when starting up in the morning and when shutting down after the day's run.

A « dead man's handle » is provided on the master controller, which if released when running, applies the brakes and cuts off the power to the motors, at the same time reducing the engine to idling speed. The main and reversing cylinders on the master controllers are mechanically interlocked, so that the controller cylinder cannot be moved unless the reversing cylinder has been placed either in the ahead or reverse position. Only one reverser key is supplied for the train. There are the usual driving accessories provided, such as a screen wiper, a horn-operating handle and the pressure gauges for the brake system.

Rolling stock.

The stock was originally built for the Bury-Holkcombe-Brook high-tension direct-current railway installation. Two third-class motor coaches of this stock, together with two third-class trailer cars, have been reconditioned and modified at the London, Midland & Scottish Railway carriage and wagon works, Derby, to meet the new requirements. In the leading coach there are fifty third-class seats non-smoking, and in the second coach eighty-five seats third-class smoking. The third coach has twelve first-class non-smoking and twenty first-class smoking seats, together with a further forty-five third-class non-smoking seats, while in the fourth or driving trailer coach there are seventy-five third-class smoking seats. Luggage compartments are provided in the two driving coaches, and the train is equipped with automatically operated collapsible folding steps, which are operated from the brake exhauster system.

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5. — Association of Electrical Engineers graduates of the Montefiore Electrotechnical Institute, rue Saint-Gilles, 31, at Liége.

Foundation of the George Montefiore triennial prize.

REGULATIONS.

Article I. — A prize provided by the accumulated interest from a capital of 150 000 francs invested in Belgian 3 % Rentes, is awarded every three years, as the result of an international competition, for the best original work presented on the scientific advancement in, and on the progress in technical applications of electricity in all fields, excluding popular works or simple compilations.

Article II. — The prize shall be known as the *George Montefiore Foundation.*

Article III. — Only works presented during the three years preceding the meeting of the

Jury shall be eligible. They should be written in French or in English, and be either printed or in manuscript. The articles should, however, be typewritten, and in all cases, the jury is at liberty to print them.

ARTICLE IV. — The jury consists of ten Electrical Engineers, five Belgians and five foreigners, under the chairmanship of the Professor-Director of the Montefiore Electrotechnical Institute, who is *de facto* one of the Belgian delegates.

Save the exceptions stipulated by the founder, the latter can only be chosen from amongst the holders of the diploma of the Montefiore Electrotechnical Institute.

ARTICLE V. — By a majority of four-fifths in each of the two sections, foreigners and Belgians (who ought for this object to vote separately) the prize can be divided in exceptional cases.

By the same majority, the jury can award a sum not exceeding one-third of the money available for a new invention, to a person not having taken part in the competition, or to a work which, whilst not altogether coming within the limits of the programme, reveals a new idea which may lead to important developments in the electrical field.

ARTICLE VI. — In the event of the prize not being awarded, or if the Jury only grants part of the money as a prize, the whole of the moneys so made available shall be added to the prize for the following triennial period.

ARTICLE VII. — The typewritten articles can either be signed or anonymous. Any work will be considered as anonymous which is not legibly signed by the author, together with his full address.

Anonymous articles should be marked outside with a private mark, repeated inside a sealed envelope attached to the package : inside this envelope the name, Chistian name, signature and address of the author are to be legibly written.

ARTICLE VIII. — Of all articles, whether printed or typewritten, twelve copies are to be sent. They are to be sent post pre-paid addressed to : M. le Secrétaire-archiviste de la *Fondation George Montefiore*, 31, rue Saint-Gilles, Liége (Belgique).

The Secretary will acknowledge receipt of the papers to the authors or to the senders giving their addresses.

ARTICLE IX. — The articles the Jury decides to print are published in the *Bulletin de l'Association des Ingénieurs électriciens sortis de l'Institut électrotechnique Montefiore.* This publication will not entail, as regards the authors of the papers, any cost, nor will it give them the right to any profit whatever. They will, however, be given twenty-five copies free of charge.

For the purposes of this publication, the English texts may be translated into French by the Association.

1929 Competition.

The value of the prize to be granted is twenty-nine thousand francs.

The latest date for the receipt of papers to be submitted to the Jury is the 30 April 1929.

The papers sent in are to be legibly headed : « Paper submitted for the George Montefiore Competition, 1927-1929 period ».

On behalf of the Administrative Council of the « Association des Ingénieurs électriciens sortis de l'Institut électrotechnique Montefiore » :

L. CALMEAU, *General Secretary.* — OMER DE BAST, *President.*

OBITUARY

Frank Percy Johnson PATENALL,

Signal Engineer of the Baltimore and Ohio Railroad;
Reporter at the London Session (1925) of the International Railway Congress Association.

We heard with much regret of the death of Mr. F. P. J. Patenall who filled with distinction the duties of reporter on the question of the « Despatching System » at the session of the International Railway Congress Association, held in London in 1925.

Mr. Patenall was born at Higham Ferrers, England, the 28 August 1864.

Whilst still young he revealed a bent for signalling work and became a much appreciated authority thereon.

He entered the service of the Lancashire and Yorkshire Railway in 1881. After two years in that Company's signalling department, he joined Messrs. Stevens and Son, Signal Manufacturers. In 1885 he went to America and joined the Union Switch and Signal Company with whom he remained until 1888. He then went to the Baltimore and Ohio Railway where from foreman he rose to be Signal Engineer.

He introduced many innovations into American signalling practice. The upper quadrant signal he patented jointly with Mr. L. F. Loree in 1903 has become the pattern in general use in the U. S. A., and his colour-position-light signal has lately been introduced on a large mileage of the Baltimore and Ohio.

Mr. Patenall was also the first to make use of electric signal lights normally kept dead, to be lighted by each approaching train. He was a prominent figure in the American Railway Association.

In the name of the Permanent Commission we have sent an expression of sympathy to the Baltimore and Ohio Railroad.

The Executive Committee.

NEW BOOKS AND PUBLICATIONS

[621 .3 (02, 532. (02, 621 .1 (02 & 665. (02]

PACORET (ETIENNE), Engineer (Arts et Manufactures), Laureate of learned and industrial Institutions. – **Traité théorique et pratique des distributions et canalisations d'électricité, d'eau, de vapeur et de gaz (Theoretical and practical treatise on the distribution of electricity, water, steam and gas).** — Volume I : Installation and distribution of electricity supply. One volume in 8vo (10 × 6 1/2 inches), 337 pages and 131 figures. — Volume II : Installation and distribution of water, steam and gas. One volume in 8vo (10 × 6 1/2 inches), 426 pages, with tables and numerous figures. — 1927, Paris (5e), 40, rue Saint-Jacques, and Dourdan (S.-et-O.), avenue de Paris, H. Vial, Publisher. — Price of each volume : 40 francs.

In modern industry, energy in various forms has to be carried distances, sometimes very short and at others very great. The needs of civilisation also necessitate the distribution of energy to numerous consumers. No factory or workshop can do without a number of distribution systems, such as of electricity, gas, water, or compressed air. The installation of mains has to conform with certain regulations in order to obtain a satisfactory degree of safety and economy in operation. The installation of these mains necessitates the employment of a great variety of materials with measuring and safety devices, which will naturally depend on the way the energy is transmitted. On the other hand, it is useful to know the method of production and the characteristics both of the power plants and the plants consuming the power. The engineer will find some very interesting information on all these questions in this book by Mr. Pacoret.

The first volume is entirely given up to electric feeder and distribution mains. It deals with the fundamental theories of electrical current, with its supply, both direct and alternating, and also with the plants making use of the supply, such as motors and transformers. The principal part deals with various mains (power and light), calculation and proof thereof, and measuring and controlling instruments.

The second volume deals with water, steam and gas mains; it also gives a few notes on hydraulics, with a brief description of the method of collecting drinking water and its purification, the description and calculation of the mains, the layout of a typical town supply, and a chapter on heating and ventilation.

The author has treated the subject of steam plants and gas supplies, and the various ways in which these forms of energy may be used, in the way in which he dealt with electricity. The great amount of practical information on the dimensions to adopt, comparative prices, regulations (although they are French they will be of interest), will no doubt be appreciated by engineers who have to get out industrial installations.

These volumes, whilst containing the necessary theoretical formulæ, set out in a logical manner data which it is often difficult to lay hands on when needed, owing to its being distributed amongst many text books and manuals.

E. M.

[385 .4 (.43)]

CENTRAL ADMINISTRATION OF THE GERMAN STATE RAILWAY COMPANY. — **Reichsbahn-Handbuch 1927 (Handbook of the State Railways, 1927).** — One volume in-quarto (8 1/4 × 5 3/4 inches), containing 700 pages and 32 maps. — Berlin, W. 8, Verlag der Verkehrswissenschaftlichen Lehrmittelgesellschaft m. b H. bei der Deutschen Reichsbahn. — Price : 16.50 Reichsmark, paper cover.

This book is the result of the collaboration of a certain number of officials, chosen from the Headquarters Administrative Staff.

It is a complete description of the German Railway system, and is divided into five parts.

The first part, which is the most important, deals with the organisation of the German State Railways. After an introduction on the constitution of the German State Railway Company, there follows, first of all, the composition of the Administrative Council and of the Management Committee, then the various divisions of the Headquarters Administration and the Central Office of the Railways, together with their essential duties. Next come the special directorates, the divisional directorates with the sub-divisions and the working lines. Further on, come chapters on :

Organisation of workshops;
Engineers Department;
Technical tests and research Department;
Traffic Department;
Rates Department.

The second part gives some details on the various consultative organisations and on institutions arising out of international railway traffic.

The third part is entirely given up to statistics and contains twenty-seven subdivisions, amongst which we may call attention to those dealing with fixed plant, rolling stock, personnel and traffic.

The fourth part deals with other means of transport, such as private lines, rail motors, and inland waterways.

The fifth part is entitled « Miscellaneous » and deals with the means adopted to increase traffic, shews the principal undertakings in which the State Railways are interested, and also gives a complete list of the official publications of the German Railways.

E. M.